PALEOPATHOLOGY

Frontispiece

FRONTISPIECE

A reconstruction depicting a prehistoric surgical operation. The drawing, based on actual material and photographs of the region, represents a primitive blanket-clad shaman using the cautery in the highlands of Peru. The patient is a woman supposed to be suffering from melancholia, for which the treatment, as judged from the skeletal remains and from analogy with modern primitive practices, was to incise the scalp in a cruciate incision and into this open cut place the oil which is bubbling on the slow fire in an appropriate medicine-man's jar, with the wisp of twisted fiber lying nearby. The operator has in his cheek a quid of coca leaves which he will apply to the wound to ease the patient's distress. The wound became violently infected and made a huge osseous lesion on the woman's skull which is fully described in Chapter XV, and shown in Figure 49 and Plates CIV-CV.

PALEOPATHOLOGY

AN INTRODUCTION TO THE STUDY OF ANCIENT EVIDENCES OF DISEASE

BY

Roy L. Moodie, Ph.D.
Associate Professor of Anatomy in the University of Illinois

University of Illinois Press
Urbana, Illinois
1923

The Collegiate Press
GEORGE BANTA PUBLISHING COMPANY
MENASHA, WISCONSIN

DEDICATED

to

SIR MARC ARMAND RUFFER

Who devoted himself to the advancement of knowledge and sacrificed his life in the cause of human freedom

PREFACE

The origin and development of disease may be traced to some extent from the pathological lesions found on the fossil bones of the ancient races of man and extinct animals, as well as from the associations of early animals of the Paleozoic. The details of the evidences for such a statement, based on an extended study of fossil lesions particularly, and a careful review of the pathology of early man as described by the students of anthropology, and represented in various collections,[1] are given in this volume.

The studies of Sir Marc Armand Ruffer, to whom this work is dedicated, on the pathology of ancient Egyptian mummies forms the groundwork of the science of Paleopathology, and I have only added to what he and his co-workers discovered by extending the subject to include the diseases of very ancient animals. A full account of Ruffer's studies is to be found in Chapter XIII.

The method of treatment in general has been to follow the succession of evidences seen in the geologic record. Thus the present account of the history of disease properly begins with the early Paleozoic or Proterozoic, 100,000,000 or more years ago,[2] and ends with the recent period. No records contained in the usual works on medical history are introduced and the attempt has been made to confine our attention chiefly to events prior to 600 B. C. This has not been entirely possible since many of the peoples studied by Ruffer are of much later date, and all of the pathology of the North and South American Indians is properly assigned to the Christian Era. The present work together with the data in August Hirsch's Handbook of Geographical and Historical Pathology contains records from the beginnings of disease in geological time down to about 1875 A. D.

These studies may be regarded as a synthesis of medical history, paleontology, and anthropology; the chief merit being the account of the pathology of fossil animals which are here given in complete form for the first time, although previous brief accounts have been published.

[1] I have been enabled to visit and examine the collections in Harvard University, American Museum of Natural History, Yale University, and the National Museum through a grant from the Research Committee of the American Medical Association.

[2] This is the more conservative of the estimates of the duration of geologic time, an account of which is given on pages 77–78.

The attempt to ally the study of the diseases of ancient animals with medical history is based on the assumption that disease as a manifestation of life is the same whether seen in man or animals. It is hoped that the details of ancient pathological lesions may aid in an understanding of the nature of disease.

The antiquity of disease and the early breaking down of the natural immunity which had protected the first races of animals is an interesting addition to our knowledge of disease. That early man may have acquired some of his diseases from the coexisting animals may be seen from the fact that the men of the old stone age, the cave bears, and other cave-inhabiting animals were often afflicted with the same maladies, attested by the osseous lesions on their numerous remains.

The problem of the extinction of great groups of animals is still one of the unsolved problems of paleontology. It was in the hope of offering definite data on the part disease has played in the extinction of vertebrate groups particularly that the study of the pathological lesions found on fossil bones was undertaken.

The lesions of fossil animals so far studied are the results of accidents, or of infections and none of them are extensive. It is improbable that any of the lesions so far studied were so severe that the life of the individual was endangered. Certainly no known ancient diseases were of sufficient virulence to have endangered the life of the race. Disease probably has been an important factor in the extinction of animals but the lesions which are to be found on the fossil bones can not be regarded as sufficiently severe to have produced widespread extinction, such as occurred many times in the history of the vertebrates. It must be remembered, however, that few of the diseases which today produce widespread epidemics are of such nature as to affect the skeleton, and paleopathology is essentially a study of the pathological changes in the bones.

The present results of the study of fossil pathology indicate the early appearance in geological time and the widespread distribution of diseases of many kinds. Most of the ancient diseases are to be regarded as chronic, infectious, or constitutional diseases which occasionally caused considerable trouble to the individual afflicted but could not have been of great importance to the species. The important fact is that disease was present millions of years ago and the evidences of its persistence are to be found in all geological periods from the Ordovician down to the present time.

Fossil bones exhibiting pathological lesions are fairly common in the collections of fossil vertebrates in America and Europe. The specimens, on which the following accounts of the most ancient diseases are based, have been studied in a number of American institutions, and several individuals have either given or loaned interesting specimens. The material in European institutions has been studied only through the literature.

Mr. H. T. Martin, at the University of Kansas, has given the use of a large number of specimens, representing the mosasaurs and dinosaurs. Mr. E. S. Riggs, of the Field Museum of Natural History, has loaned material for study. The fractured and healed dinosaur rib, and the fractured tibia and fibula of an early carnivore are in his collections. Dr. S. W. Williston, late director of the Walker Museum, University of Chicago, has loaned the interesting radius of a Permian reptile showing the type of ancient fracture. Dr. E. C. Case, of the University of Michigan, has loaned additional material from the Permian. Dr. R. S. Lull, of Yale University, has assisted in the study of the numerous lesions contained in the Marsh collection of fossil vertebrates by photographs and advice. At the American Museum of Natural History material of all kinds has been placed at my disposal and I am indebted to Dr. W. D. Matthew and Dr. W. K. Gregory for photographs. Dr. John M. Armstrong of St. Paul, Minnesota, presented the specimens of mosasaur vertebrae on which is preserved the unique *osteoma*. Mr. Harold Cook has loaned interesting fossil mammals.

Dr. C. D. Walcott, of the Smithsonian Institution, has furnished the figures of the oldest known bacteria, and the material for Plates I-V. Dr. Charles Schuchert, of Yale University, has suggested the theoretical aspects of Paleopathology. Dr. R. S. Bassler, of the U. S. National Museum, furnished a photograph of the earliest tsetse fly, and has criticised the work on crinoid tumors. Dr. John C. Merriam, of the Carnegie Institution of Washington, has furnished data on the pathology of the Rancho la Brea fauna. Dr. Aleš Hrdlička, of the U. S. National Museum, has guided the search for pathological lesions among the early North American Indians, and has read most of the manuscript of those parts of the work dealing with ancient human races. Dr. Edward W. Berry, paleobotanist at Johns Hopkins University, has written the chapter on Paleophytopathology, Chapter III. Although the work in the book is a combination of all materials available, I am solely responsible for their arrangement and expression.

Since I have been trained chiefly in vertebrate paleontology, and have no extensive acquaintance with modern pathology I have relied for advice and help on pathological questions on my colleagues of the Department of Bacteriology and Pathology, University of Illinois. This advice and help have been cheerfully given at all times, and I have had complete access to the pathological collection in their charge.

The illustrations throughout the book are largely the work of Mr. Willard C. Shepard, Mr. Tom Jones, and Miss Genevieve Meakin. Acknowledgment of other figures is given in each case. The frontispiece is published through the courtesy of W. B. Saunders Company.

Roy L. Moodie

Department of Anatomy
University of Illinois, Chicago
July 1, 1922.

TABLE OF CONTENTS

PAGE

Preface.... 9
List of Illustrations.... 18

INTRODUCTION

Definition and Scope of Paleopathology.... 21
Paleontological Evidences.... 25
Definition of Disease, as Used in This Work.... 29
Evidences of Disease among Fossil Plants.... 29
Apparent Immunity of Early Paleozoic Animals to Infectious Diseases.... 30
Regeneration.... 32
Immunity in Modern Invertebrates.... 34
The Origin of Disease.... 35
Increase of Disease in Geological Time.... 36
Table of Geological Evidences.... 38
Descriptions of Figures 1-4 and Plates I-VII illustrating the Introduction.... 41
Figures 1-4 and Plates I-VII following page.... 41

CHAPTER I

THE DEVELOPMENT OF PALEOPATHOLOGY

Historical Account of Studies on Ancient Diseases.... 61
Tabular Review of Literature Dealing with Paleopathology.... 72
Nature of Ancient Diseases.... 75
Persistence of Certain Types of Disease.... 75
Tabulation of the Antiquity of Certain Pathological Processes.... 76
Measurement of Geologic Time.... 77
Descriptions of Figures 5-7 and Plates VIII-X illustrating Chapter I.... 79
Figures 5-7 and Plates VIII-X following page.... 79

CHAPTER II

THE ORIGIN OF DISEASE

Speculations as to the Antiquity of Disease.... 91
Geological Beginnings of Disease.... 92
Tabulation of All Geological Evidences.... 92
Lesions of Parasitism Among Paleozoic Animals.... 96
Pathology of the Early Fishes, Amphibians, and Reptiles.... 97

CHAPTER III

PATHOLOGICAL CONDITIONS AMONG FOSSIL PLANTS

By Edward W. Berry, Johns Hopkins University

Introduction.... 99
Extinction.... 99
Parasitism.... 101
Callus and Injury.... 101

PAGE
Fossil Fungi 103
Bacterial Activity 103
Spot Fungi 104
Activities of Insects 106
Teratology 107
Descriptions of Plates XI-XIII illustrating Chapters II and III 109
Plates XI-XIII following page 109

CHAPTER IV

Callus and Fracture in Fossil Vertebrates

The Oldest Known Fractures 116
Histology of Permian Fractures 118
A Triassic Fracture 121
Fracture and Callus in the Dinosaurs 122
Fractures Among the Early Mammals 124
Fractures Among the Pleistocene Mammalia 126
Fractures in the American Bison 129
Descriptions of Figures 8-10 and Plates XIV-XXVI illustrating Chapter IV. 131
Figures 8-10 and Plates XIV-XXVI following page 131

CHAPTER V

Deforming Arthritides in the Early Vertebrates

Arthritic Lesions in the Dinosaurs 161
Spondylitis Deformans in the Dinosaurs 164
The Fossilization of Blood Corpuscles 165
Arthritides in the Mosasaurs 169
Osteomata Among Modern Vertebrates 171
Multiple Arthritis in a Mosasaur 171
Cretaceous Osteoperiostitis with Arthritic Lesions 172
History of Spondylitis Deformans 173
Spondylitis Deformans in Eocene Mammals 174
Spondylitis Deformans in a Miocene Crocodile 174
Spondylitis Deformans in a Pliocene Camel 175
Spondylitis Deformans among Pleistocene Mammals 176
Descriptions of Figures 11-18 and Plates XXVII-XLIII illustrating Chapter V 179
Figures 11-18 and Plates XXVII-XLIII following page 179

CHAPTER VI

Caries and Alveolar Osteitis Among Fossil Vertebrates

Caries in Permian Vertebrates 222
Dental Disturbances Among Extinct Reptiles and Mammals 222
Caries in the Mastodon 224
An Abscess in the Mastodon 224
Dental Caries in the Mastodon 225
Premaxillary Lesion in an African Gorilla 229
Descriptions of Figures 19-22 and Plates XLIV-XLVI illustrating Chapter VI 231
Figures 19-22 and Plates XLIV-XLVI following page 231

CHAPTER VII

Chronic Infections Among Fossil Vertebrates

Osteomyelitis in the Permian 244
Necroses and Hyperostoses in the Dinosaurs 245

PAGE
A Large Necrotic Sinus in a Mosasaur 246
A Symmetrical Lesion in an Early Dog 246
Mesozoic Pathology 247
Actinomycosis in a Fossil Rhinoceros 249
Hyperostoses or Pachyostoses (Giantism) in Ancient Animals 251
Osteomalacia in an Eocene Carnivore 252
Traumatic Lesions and Other Pathology of the Pleistocene Mammals 253
Skeletal Anomalies Among Fossil Vertebrates 254
Descriptions of Figures 23-25 and Plates XLVII-LVIII illustrating Chapter VII 255
Figures 23-25 and Plates XLVII-LVIII following page 255

CHAPTER VIII

PARASITISM AMONG FOSSIL ANIMALS

The Origin of Parasitism 283
Symbiosis Among Fossil Animals 284
Parasitism of Carboniferous Crinoids 285
Theoretical Aspects of Paleopathology 287
A Case of Pleistocene Parasitism 288

CHAPTER IX

THE BACTERIOLOGY OF PAST GEOLOGICAL AGES

The Oldest Bacteria 290
Bacteria and Thread-mould in the Devonian 291
Bacteria of the Coal and Other Fossil Bacteria 294
Coprolites of the Autun Schists 295
Bacteria of the Coprolites 295
Fossil Bacteria Analogous to Those Which Produce Dental Caries 300
Bacteria in the American Permian 303
Microscopic Observations on Coprolites from the American Permian 304
Descriptions of Figure 26 and Plates LIX-LXV illustrating Chapters VIII and IX 307
Figure 26 and Plates LIX-LXV following page 307

CHAPTER X

OPISTHOTONOS AND ALLIED PHENOMENA AMONG FOSSIL VERTEBRATES

Frequency of Opisthotonos among Fossil Vertebrates 324
Opisthotonos among Pterodactyls 325
The Opisthotonic Attitude among Ancient Birds and Dinosaurs 326
Pleurothotonos 327
Phenomena among Fossil Fishes 328
Opisthotonos in Man 329
Phenomena as Manifestations of Disease 330
Summary 332
Descriptions of Figure 27 and Plates LXVI-LXVIII illustrating Chapter X 333
Figure 27 and Plates LXVI-LXVIII following page 333

CHAPTER XI

THE EXTINCTION OF RACES

Disease as a Factor in Extinction 342
The Influence of Diseases of the Skeleton in the Extinction of Races 344
Pathology of the American Mastodon 344

PAGE

CHAPTER XII

Pathology of the Early Human Races

Pathological Femur of Pithecanthropus 347
Pathology of the Men of the Old Stone Age (Paleolithic) 348
Neolithic Injuries 349
Evidences of Syphilis among Ancient Men 353
Prehistoric Trephining 356
The Use of the Cautery among Neolithic and Later Primitive Peoples as a Cause of Skull Lesions 358
The Amputation of Fingers among Primitive Races 361
Descriptions of Figures 28-35 and Plates LXIX-LXXIII illustrating Chapters XI and XII 365
Figures 28-35 and Plates LXIX-LXXIII following page 365

CHAPTER XIII

Diseases of the Ancient Egyptians

Biographical Sketch of Sir Marc Armand Ruffer 387
Diseases of the Ancient Egyptians 388
Chronological Table of Kings of Egypt 389
Arteriosclerosis in the Aorta of the Pharaoh of the Exodus 392
Other Arterial Lesions among Early Egyptians 393
Histological Studies on Egyptian Mummies 395
An Eruption Resembling Smallpox 395
Vesical Calculus 396
Early Evidences of Schistosomiasis 396
Rickets in Ancient Egypt 397
Appendicitis 398
Symmetric Osteoporosis of the Skull 398
Prolapsus Viscerum 400
Hydrocephalus in Early Egypt 401
A Psoas Abscess 402
A Pelvic Osteosarcoma 402
Osseous Lesions in Early Egyptians 403
Poliomyelitis 408
Trephining in Egypt 409
Lesions in the Mummified Animals of Egypt 410
Syphilis in Egypt 411
Descriptions of Figures 36-41 and Plates LXXIV-LXXXVII illustrating Chapter XIII 413
Figures 36-41 and Plates LXXIV-LXXXVII following page 413

CHAPTER XIV

Disease Among the Pre-Columbian Indians of North America

Evidence of Pathology among American Aborigines 452
Knowledge of Surgery 453
Descriptions of Figures 42-45 and Plates LXXXVIII-XCVII illustrating Chapter XIV 457
Figures 42-45 and Plates LXXXVIII-XCVII following page 457

PAGE

CHAPTER XV

Diseases of the Ancient Peruvians

Uta, as Depicted on Ancient Water Jars 489
Trephining in South America 490
Diseases of the Teeth 492
Descriptions of Figures 46-49 and Plates XCVIII-CXVII illustrating Chapter XV 495
Figures 46-49 and Plates XCVIII-CXVII following page 495
BIBLIOGRAPHY 543
INDEX 559

LIST OF ILLUSTRATIONS

		PAGE
Frontispiece—Reconstruction of a Prehistoric Surgical Operation.....facing		3
Figure 1.	Pre-Cambrian Bacteria	42
Figure 2.	Graph showing Increase of Disease	44
Figure 3.	Paleozoic Examples of Pathology	44
Figure 4.	Geological Diagram	46
Figure 5.	Fractured Femur of Cave-bear	80
Figure 6.	Cuvier	82
Figure 7.	Virchow, von Walther and Zittel	84
Figure 8.	A Long-spined Permian Reptile, Edaphosaurus	132
Figure 9.	Restoration of a Three-horned Dinosaur, Triceratops	134
Figure 10.	Restoration of Moropus	134
Figure 11.	Fracture of Mastodon Rib	180
Figure 12.	Normal Dinosaur Vertebrae	180
Figure 13.	Restoration of Dinosaur with Nervous System	180
Figure 14.	Sawn Section of Fossil Hemangioma	182
Figure 15.	Spondylitis Deformans in Tail of Diplodocus	182
Figure 16.	Restoration of Mosasaur	184
Figure 17.	Chalk-cliffs of Western Kansas	186
Figure 18.	Normal Arm of a Mosasaur	186
Figure 19.	Diseased Molar of Recent Horse	232
Figure 20.	Joseph Leidy	234
Figure 21.	Median Section of a Diseased Whale's Tooth	236
Figure 22.	Diseased Camel Incisor	236
Figure 23.	Skeleton of Camptosaurus	256
Figure 24.	Actinomycosis in a Pliocene Rhinoceros	258
Figure 25.	Diseased Vertebra of a Saber-tooth Cat	258
Figure 26.	Crinoids and Starfish	308
Figure 27.	Stenomylus Hill	334
Figure 28.	Distribution of Trypanosomiases	366
Figure 29.	Distribution of Trephining throughout the World	368
Figure 30.	Relations of Early Human Types	370
Figure 31.	Schemata of Scalp Incisions	372
Figure 32.	Map of Neolithic and Recent Trephining	372
Figure 33.	Silhouettes of Hands	374
Figure 34.	Mutilated Hands of a Bushman	374
Figure 35.	Primitive Scarification	376
Figure 36.	Sir Marc Armand Ruffer	414
Figure 37.	Louis Charles Lortet	416
Figure 38.	Map of Egypt	418
Figure 39.	Osteoporosis	420
Figure 40.	Pott's Disease	422
Figure 41.	An Ancient Flint Knife	422
Figure 42.	Pathology of pre-Columbian Times	458
Figure 43.	Primitive Surgical Appliances	460

			PAGE
Figure 44.	A Bark Orthopedic Corset	facing	462
Figure 45.	Distribution of North American Indian Tribes		464
Figure 46.	The Empire of the Incas		496
Figure 47.	Goundou		498
Figure 48.	Relation of Tribes in North and South America		500
Figure 49.	The Effects of the Actual Cautery in Ancient Times		502
Plate I.	Middle Cambrian Annulata		48
Plate II.	Middle Cambrian Crustaceans		50
Plate III.	Lower Cambrian Trilobites		52
Plate IV.	Cambrian Brachiopods		54
Plate V.	Middle Cambrian Medusa and Holothurian		56
Plate VI.	Miocene Normal and Pathologic Clams		58
Plate VII.	Photomicrographs of Clam Shells		60
Plate VIII.	Pathologic Pleistocene Mammals		86
Plate IX.	Traumatisms among Fossil Reptiles		88
Plate X.	Mesozoic Pathology		90
Plate XI.	Paleozoic Examples of Parasitism		110
Plate XII.	Fossil Plants		112
Plate XIII.	Diseased Fossil Leaves		114
Plate XIV.	The Oldest Known Fractures		136
Plate XV.	Permian Pathology		138
Plate XVI.	Histology of Permian Callus		140
Plates XVII-XIX.	Photomicrographs of Ancient Callus and Fracture		142-146
Plate XX.	Skeleton of Titanotherium, with Fractured Rib		148
Plate XXI.	Sections of a Permian Osteomyelitis		150
Plate XXII.	Fractures in Moropus		152
Plate XXIII.	Traumatic Lesions in Dinosaurs and in a Mammal		154
Plate XXIV.	Fracture with Pseudarthrosis in the American Bison		156
Plate XXV.	Fracture in the American Mastodon		158
Plate XXVI.	Fracture and Necrosis in Ancient Reptiles and the Muskox		160
Plate XXVII.	Distinguished Paleontologists		188
Plate XXVIII.	Fossil Reptiles		190
Plate XXIX.	Deforming Arthritides in the Dinosaurs		192
Plate XXX.	A Fossil Hemangioma		194
Plate XXXI.	Microscopic Study of Fossil Tumor		196
Plate XXXII.	Histology of Dinosaur Bone		198
Plate XXXIII.	Histology of Fossil Hemangioma		200
Plate XXXIV.	Cretaceous Osteoperiostitis		202
Plate XXXV.	The Oldest Known Fibers of Sharpey		204
Plate XXXVI.	Microscopic Study of Fossil Lesion		206
Plate XXXVII.	Nature of Fossil Perforating Fibers		208
Plate XXXVIII.	Histology of Mosasaur Bone		210
Plate XXXIX.	A Cretaceous Osteoma		212
Plate XL.	A Sawn Section through a Fossil Osteoma		214
Plate XLI.	Multiple Arthritis		216
Plate XLII.	Pleistocene Pathology		218
Plate XLIII.	History of Spondylitis Deformans		220
Plate XLIV.	Pathology of a Three-toed Horse		238
Plate XLV.	An Anomalous Mastodon Molar		240
Plate XLVI.	Pathology of Teeth		242
Plate XLVII.	Famous Fossil Beds		260
Plate XLVIII.	Mesozoic Pathology		262

PAGE
Plate XLIX. A Cretaceous Necrosis........................facing 264
Plate L. Pathology in Two Dinosaurs........................ 266
Plate LI. Eocene Osteomalacia.............................. 268
Plate LII. Ancient Chronic Infections........................ 270
Plate LIII. Pathology in Fossil Mammals 272
Plate LIV. Pleistocene Pathology.............................. 274
Plate LV. Pleistocene Osteoperiostitis......................... 276
Plates LVI-LVII. Pathology of American Bison....................278-280
Plate LVIII. Chronic Infections 282
Plate LIX. Paleozoic Parasitism............................... 310
Plate LX. The Oldest Known Bacteria......................... 312
Plate LXI. Fossil Feces....................................... 314
Plate LXII. Ancient Bacteria and Fungi......................... 316
Plate LXIII. Bacteria in Fossil Fish Bone........................ 318
Plate LXIV. Evidences of Bacteria in Fish Bone.................. 320
Plate LXV. Microscopic Structure of a Permian Coprolite.......... 322
Plates LXVI-LXVIII. Opisthotonos and Allied Phenomena 336-340
Plate LXIX. Neolithic Pott's Disease............................ 378
Plate LXX. Stone Age Injuries................................ 380
Plate LXXI. Ancient Human Pathology.......................... 382
Plate LXXII. Neolithic Trephining............................. 384
Plate LXXIII. Primitive Surgery................................ 386
Plate LXXIV. Ancient Egyptian with Pott's Disease............... 424
Plate LXXV. Ancient Egyptian Pathology........................ 426
Plate LXXVI. Mummified Organs............................... 428
Plates LXXVII-LXXXI. Ancient Egyptian Pathology...............430-438
Plates LXXXII-LXXXIII. Primitive Splints.....................440-442
Plates LXXXIV-LXXXV. Abnormalities and Pathology of Ancient Egyptian Teeth..................................444-446
Plates LXXXVI-LXXXVII. Ancient Egyptian Pathology............448-450
Plates LXXXVIII-XCVII. Pre-Columbian Pathology of North America.466-484
Plates XCVIII-CXVII. Ancient Peruvian Pathology.................504-542

INTRODUCTION

Definition and scope of paleopathology. Paleontological evidences. Definition of disease as used in this work. Evidences of disease among fossil plants. Apparent immunity of early Paleozoic animals to infectious diseases. Regeneration. Immunity in modern invertebrates. The origin of disease. Increase of disease in geological time. Table showing geological antiquity of pathological processes. Descriptions of Figures 1-4 and Plates I–VII illustrating the introduction. Figures 1-4 and Plates I-VII.

DEFINITION AND SCOPE OF PALEOPATHOLOGY

The study of the evidences of injury and disease among ancient man and fossil animals is known as *Paleopathology.* The term was first given in the Standard Dictionary, Volume 2, 1895; where it is defined as "the science of pathological conditions in the organs of extinct or petrified animals."[1] A later edition (1913) states that it is "the study of pathological conditions in fossil or extinct organisms." The term was first applied to a discussion of definite results by Sir Marc Armand Ruffer,[2] who applied the term, apparently unaware of the earlier American definition, to the methods and results he had developed in studying the pathological anatomy of the ancient Egyptian mummies. He defined the term in the following words:

> Paleopathology is the science of the diseases which can be demonstrated in human and animal remains of ancient times (1913.1).[3]

Although Ruffer is thus rightly given the credit for the introduction of the term "Paleopathology" into medical literature, yet it was in use for many years prior to Ruffer's paper, both as a term and as a science in America. It has been studied extensively especially at Albany, New York, where, in the laboratories of the State Museum, John M. Clarke has pursued the only American studies dealing with the question of early associations, parasitism, and other benign pathological conditions, among the Paleozoic invertebrates. It is an inter-

[1] I am indebted to Dr. Gilbert Van Ingen for calling my attention to this definition. It precedes all others.

[2] A discussion of the life and works of Ruffer is to be found in the Chapter (XIII) on "Diseases of the Ancient Egyptians."

[3] The numbers throughout the text indicate the references at the end of the book, where there is a bibliography of the works cited, quoted or from which illustrations have been taken. The bibliography has been largely restricted to definite studies on paleopathology, accessory references being given in footnotes.

esting fact that the two definitions, evolved in Egypt and in America, independent of each other, are so similar in their scope.

The significance of the study of paleopathology in its relation to a proper understanding, not only of ancient afflictions of extinct animals but of modern human diseases as well has been discussed by Klebs (1917. 1 and 2). A further discussion and extension of its meaning to include not only the diseases on the mummified animal[4] and human remains of Egypt, but those of prehistoric man and fossil vertebrates as well, have been given in a series of papers by the author, dealing with various aspects of the subject as seen in the paleontological and anthropological material. The field thus involved in the subject of paleopathology includes the resources of medical history, as seen in Ruffer's work, paleontology and anthropology.

The present work is a summary of existing knowledge of the so-called *prehistoric* and especially the pre-human evidences of disease (prior to 500,000 B. C.) of the extinct vertebrates, with a brief account of the origin of disease. This latter phase of the subject is a rather special field and has been fully dealt with in a separate work by Dr. Clarke (1921). The term *prehistoric*, of course, usually refers to events prior to the details of recorded human history, and is variously designated according to the region under discussion. Thus in Egypt any grave earlier than the time of the first Dynasty[5] is often referred to as prehistoric or predynastic. Since the calendar was introduced into Egypt in the year 4241 B. C. an ancient burial of predynastic times may have an antiquity of from five to six thousand years or more, there being no definite measurements of time prior to this date. In France LeBaron (1881) defines the prehistoric[5a] period as closing about 222 B. C., and several centuries later in Algeria. It will be evident that while history was being recorded in Babylonia and Egypt, contem-

[4] Lortet and Gaillard (1903–1909) have published a magnificent memoir on the nature of the ancient mummified human and animal remains of Egypt, in which Poncet has discussed the pathological evidences. Ruffer (1910.1) denies some of Poncet's conclusions, especially his diagnosis of tuberculosis, basing his opinion on more material than was at Poncet's disposal. Further discussion of these interesting results is in Chapter XIII.

[5] The first Dynasty began with the accession of Menes, 3400 B. C., according to Breasted—1909—History of Egypt, p. 597. The first and second dynasties, extending over a period of 420 years (3400–2980 B. C.), were represented by eighteen kings. There is great diversity of opinion as to the proper chronology in Egypt. I have adhered throughout to that given by Breasted. This is quoted in full, for the reader's convenience, in Chapter XIII.

[5a] This term was introduced in 1851 by Sir David Wilson, in his work "The Archeology and Prehistoric Annals of Scotland," where he uses it to refer to the races of man prior to written history.

porary events elsewhere were of the nature of prehistoric data but only for the region in which they occurred.

Prehistoric events in America are usually regarded simply as pre-Columbian, and they are so-called in this work. Since the written records of American events prior to the coming of the Spaniards are very rare, being largely confined to the incomplete Maya[6] records, the distinction of events in either North and South America as certainly of pre-Columbian date is well nigh impossible. The records contained in this book have been ascertained with care but are given with reservations as to the exact date. The archeological evidences of the Maya, Aztec, and Inca civilizations indicate a previous history of many hundreds of years[7] of which we know very little. The term prehistoric has no significance when applied to paleontological data, and Klebs (1917.1) has suggested that it be dropped altogether. The transition from the prehistoric to the historic was everywhere a slow and gradual process, and the boundary is not a sharp one.

It is interesting to note that the history of disease and injury, from the first geological evidences at present obtainable, down to the historical data given in August Hirsch's "Handbook of Geographical and Historical Pathology," in which there is a review of the evidences from about 600 B. C. to 1875 A. D., may be seen as a series of consecutive events from the introduction of diseased conditions among animals and plants down to the present time. There can thus be no doubt that many of the existing diseases have a very great antiquity, since from their ravages in ancient times it can be seen that they have a history extending back into geological time for many millions of years.

It is thought worth while to review and assemble, in connection with the study of fossil lesions, the results of Ruffer, already referred to, Elliot Smith, Wood Jones, Fouquet, Rietti, Gaillard and Lortet, and others on the pathological anatomy of the mummified remains of ancient animal and human races from the graves of Egypt. Their re-

[6] C. P. Bowditch: The Numeration, Calendar Systems, and Astronomical Knowledge of the Mayas. 1910, 340 pp. Peabody Museum of Harvard.

A more popular account of the Mayas is found in the work of Herbert J. Spinden: Ancient Civilizations of Mexico and Central America. New York, 1917 (American Museum of Natural History Handbook, Series 3).

[7] Clark Wissler: The American Indian, 1917, p. 270. Clements R. Markham: The Incas of Peru, Chapters I and II.

An excellent account of the archeology of Peru is contained in the work of E. George Squier: Peru, Incidents of Travel and Explorations in the Land of the Incas, London, 1877. This still remains after forty years the best and most readable account of the ancient ruins of Peru.

sults are to be found in scattered memoirs and reports[8] to which access can be had only in a special library. Sir Marc Armand Ruffer had planned a volume of antiquarian studies which would probably have been a permanent record of his unique and memorable discoveries in Paleopathology. Doubtless he would have had in this work a careful summary of all work done on the pathology of ancient Egypt.[9]

The review given below in the chapter on "Diseases of the Ancient Egyptians" is my own interpretation of the work gleaned from many scattered sources.[10] Doubtless, from a certain standpoint, the material used by these authors might be regarded as *fossil*, meaning something "dug up" (L. fossilis = dug up). The term fossil, however, as used in this volume refers to material which is thoroughly or partially petrified,[11] the age of which must be reckoned by geological standards. The studies on ancient Egypt have been briefly reviewed and summarized by Garrison (1917), Klebs (1917), and Sudhoff (1915, p. 33), and the author has referred to them at various times. An extensive account is given further on in this volume.

[8] These are listed in the bibliography under the authors.

[9] Lady Alice Ruffer writing under dates of December 9th, 1918, and July 24th, 1919 says: "When leaving on that fatal mission to Salonika, my husband gave me the headlines and notes of six papers which he intended to write. These have been worked up to the best of my ability, but of course I have not dared the summing up and conclusions which Sir Armand had arrived at, for I did not know sufficiently what was in his mind. One of these papers, a short one, on Prehistoric Trephining (Ruffer, 1918.1) has already been published.

"About a collected memoir summarizing all my husband's results in Paleopathology; such a thing does not exist. He intended to retire this year (1919) from Government Service and devote himself to his science and write a great memoir on it."

Lady Ruffer, herself, has subsequently brought about the publication of a collected memoir of Sir Ruffer's studies on the Paleopathology of Egypt (Ruffer, 1921).

[10] Lady Ruffer has kindly sent me a set of her husband's studies on paleopathology, and manuscript copies of his unpublished essays, which have proved extremely useful.

I owe to the kindness of Dr. Claude Gaillard, Director of the Museum d'Histoire Naturelle of Lyons, France, a copy of the splendid work by Lortet and himself on the mummified fauna of Egypt.

[11] An excellent discussion of fossils in general and the nature of fossilization processes has been given by L. P. Gratacap: Fossils and Fossilization. Amer. Naturalist, XXXI, 902; 16, 191, 285, 293, 1896–7. He defines a fossil as "any indication of life which has become entirely or partially altered in its substance or condition by the mineral or chemical agencies of its environment."

Schuchert (Text-book of Geology, II, 1915, p. 430) regards fossils or petrifactions as the remains or natural impressions or even traces of plants and animals which have lived at some time previous to the present and are now buried in stratified rocks. This definition would exclude all artificial burials.

See also R. S. Lull: Organic Evolution, 1917, N. Y., 409–420.

See also in this connection: "Fossils—are they merely 'prehistoric' or must they also be 'geologic,'" Science, N. S., LIII, 258, 1921.

The studies of Aleš Hrdlička (1908–1916), Langdon (1881), Fletcher and other writers on the pathological anatomy of the North American Indians, and of Hrdlička (1914), Eaton (1916), Tamayo, Palma, Escomel and other students of the ancient Peruvians have not been neglected in summarizing our knowledge of Paleopathology. This literature has been supplemented by a first hand study of collections in various museums, which have loaned or photographed material for this purpose.

The meager details of the diseases of fossil man have been largely gleaned from the literature, or confirmed by the study of casts of the inaccessible originals. This subject has been already briefly reviewed (Moodie, 1918.5) and is recast here in more complete form in Chapter XII.

PALEONTOLOGICAL EVIDENCES

Paleontological data add considerable information to the study of the antiquity of disease. The causes of disease or injury among ancient animals may be grouped under the following headings:[12]

(1) Mechanical injuries through natural causes, such as crushing or breaking of bones, shells or tests by wave shock or impact in falling.

(2) Injuries caused by predatory animals in water and on land, such as crabs, cephalopods, sharks, and carnivorous mammals. Such evidences are commonly seen in Cretaceous reptiles.

(3) Parasitic lesions caused by the presence of worms, sponges, corals, algae or other organisms which become attached on or bore into shells of living animals or the unprotected columns of crinoids. Such lesions furnish our earliest evidences of pathology. This type of injury is commonly seen in the irregularly thickened walls of oyster shells which have been attacked by sponges.

(4) Bacterial sinuses indicated in bony tumors, decayed teeth, necrotic foci of many kinds seen in vertebrates. Bacterial diseases of fossil plants and lesions produced by fungi belong in this category.

(5) A peculiar kind of pathology is caused by poisoning of the waters in which the animals lived. This may result in hypertrophy, abnormalities of form or a depauperized fauna.

(6) A weakened or senile condition manifested by loss of vigor attendant upon phylogentic old age of a race, by which the members have become unable to cope with changes in their environment, with

[12] Dr. Gilbert Van Ingen has for some years given a lecture to his students at Princeton on Paleopathology, and the following outline is taken from the abstract of his lecture which he has sent me. The lecture is illustrated by a series of fossil pathological invertebrates.

resulting degeneracy and final extinction. The production of spines is often an external manifestation of phylogenetic old age.

The study of the lesions so far known among fossil animals indicates nothing new in the nature of pathological processes but simply extends our knowledge of pathology to a vastly earlier period than had previously been known. It seems quite probable that some of the diseases exhibited by the extinct vertebrates went out of existence with the race of animals which were afflicted. If this proves to be true it is an interesting opportunity to study the details of lesions of extinct diseases. There seems to be little possibility, from a study of paleontology, of determining the fundamental causes of disease other than is already known; for disease is apparently one of the manifestations of life, and has followed the same lines of evolution and development as have plants and animals, and has probably been directed by the same factors. Life processes in the past have taken place in the same manner as they do today, and there is no reason to suppose that pathological evidences will be of a different type.

Such a study as the present may, however, throw light on the origin, or at least the antiquity, of many of the diseases to which the human race is a prey. A knowledge of the pathological processes which have taken place in animals of geological antiquity may aid in an understanding of the general nature of disease. A study of life in its widest scope forms the fundamentals of medicine. Observable data of any nature will certainly be of assistance and possibly the evidences of remote periods, since they are on *a priori* grounds simpler, may be viewed more clearly than the recent evidence.

The literature of vertebrate paleontology contains a number of incidental references to the diseased nature of the fossilized bones of fishes, reptiles, birds and mammals, the lesions described indicating a variety of diseases, some of which are not uncommon today. It is manifestly impossible to diagnose correctly, on the basis of our modern knowledge of recent diseases, all of the lesions which are preserved in a fossil condition. Great care has been exercised in assigning any of the fossil lesions to a definite cause and few generalizations have been attempted on the incomplete data at hand. In the extinction of the ancient races certain diseases doubtless became extinct with them, and if extinct they have no name but represent an unknown phase of disease. Then, too, many diseases may be quiescent over long periods of time and reappear centuries later in a modified form. Thus the disease known as *sweating sickness*, the characteristics of which are carefully

described by Hecker (1846) for the Middle Ages, has reappeared in modified form during the past two decades in western Europe, after being long regarded as an extinct disease. In addition to a careful summary of paleontological literature many original observations are recorded, based on the study of material in various museums.

Geological evidences of the diseased state of animals are necessarily restricted to pathological lesions on the hard parts of fossil animal remains. Soft parts are seldom preserved among the fossil vertebrates, many of the softer organs being very rarely represented by impressions or casts of stone. Occasionally, as in the case of the Devonian shark described by Dean,[13] the histological details of the muscle and kidney are preserved. Certain very interesting specimens of fossil brains of a small Carboniferous ganoid fish have also been made known.[14] These few specimens of soft parts, however, have not been subject to disease, and the evidences of pathology, meager as they are, must be read from the osseous lesions. Since the pathological changes which affect the hard parts of animals today are relatively few when compared to the diseases which afflict the body as a whole, it is to be assumed that the paleontological evidences of disease are but partial indications of the prevalence of pathological conditions in remote geological epochs. When we add to this the fact that only a small portion of the animal remains preserved are ever recovered, and only a small fraction of each fauna is fossilized, we are able to appreciate the insignificance of the record. The details are meager, but since they are all we have, they may be deemed worthy of consideration.

We are just beginning to appreciate the significance of the study of paleopathology, and the application of pathological methods to the study of fossil lesions will bring new light to bear on many phases of the problem. The comparative scantiness of facts so far brought out and the difficulties of research ought not to hinder the successful prosecution of the work. We will have to await results to determine what the final conclusions may be; the immediate facts being to call attention to the presence of characteristic lesions of injury and disease far back in geological time. It is very interesting, if not important, to find in past geological ages evidences of pathological processes which are so

[13] Bashford Dean: Studies on Fossil Fishes. Mem. Am. Mus. Nat. Hist., N. Y. ix, pt. v 232, 1909.

[14] Roy L. Moodie: A New Fish Brain from the Coal Measures of Kansas, with a Review of Other Fossil Brains. J. Comp. Neurol., xxv, 135–181, 19 figs. 1915. Contains an annotated bibliography of papers on the soft parts of extinct vertebrates.

familiar to us today. If we can trace the known lesions to any definite cause among the extinct animals it will be a step toward the completion of a new branch of pathology, dealing with the most ancient aspects of that science.

The importance of this branch of study in the interpretation of medical history and modern medicine has been outlined by Klebs (1917.1) in the following words:

> We need only consider what definite influence diseases exert in our individual lives, what profound social upheavals were brought about through the influence of epidemics, less perceptibly perhaps but none the less strongly, through widespread chronic ailments, through professional diseases, how whole districts and countries are forsaken because disease made them uninhabitable, how disease affecting early childhood and others producing sterility led to the gradual extinction of whole peoples. . . . For the grasp of such problems, the study of disease as it appears to us now does not suffice, the traces left during immense periods of time have to be taken into account and it is in just such questions, not approachable by other methods, that paleopathology in time to come may furnish important solutions.

Most students of both vertebrate and invertebrate fossils have neglected the evidences of disease. In fact diseased or injured fossils are often discarded because they lack some typical aspect in which the student is interested. There is thus a wide field of study especially among the more ancient forms of life which has not yet been cultivated. Even men like Leidy, a trained anatomist and an eminent medical teacher, paid scant attention to the evidences of pathology among the many thousands of fossil remains of reptiles and mammals in the description of which he attained such distinction in the paleontology of North America. He did, however, refer to the subject for he figured and briefly described an interesting diseased phalange of an early oreodont and discussed rather fully the occurrence of *caries* in the molar tooth of a Pleistocene mastodon from Florida (Leidy, 1886). Cuvier added to the discussion of this phase of paleontology by the description of a few lesions especially calling attention to a fractured and healed skull (Cuvier, 1820) of an old *Hyaena* from the Pleistocene of France, and a fractured femur of the Oligocene *Anoplotherium*.

Doubtless one reason for the neglect of the study of Paleopathology was the great amount of interest early workers found in the discovery and descriptions of new forms of animal life, as well as in interpreting the significance of these forms in the principles of organic evolution, which, during the greater part of the past century, attracted the attention of the best biological thought. The science of paleontology, starting out in this way, has now reached the stage where it seems propitious

to add to its biological aspect the interrelation of medical history and pathology.[15]

DEFINITION OF DISEASE AS USED IN THIS WORK

Disease, for the purpose of discussion in paleopathology, may be defined[16] as any deviation from the healthy or normal state of the body which has left a visible impress upon the fossilized or mummified remains. These evidences may take the form of broken bones, which have been more or less completely healed, with or without the formation of callus, but tumors, necroses, hyperplasias, and deforming arthritides of all kinds constitute the more obvious indications of disease or injury. The intimate associations of earlier Paleozoic animals often resulted in a pathological relationship which is essentially one of disease. Such associations belong to the earlier stages of disease in which the lesions are less obvious, though the result was none the less serious to the animal affected.

Only the diseases of fossil animals, chiefly those of the vertebrates, and of ancient man are considered. This is done with a full realization of the enormous domain of phytopathology and the pathology of the invertebrates, and the significance of the diseases of these forms in an interpretation of the scope of paleopathology in its broadest aspects. Whetzel[17] in reviewing the development of phytopathology does not mention the domain of fossil plant pathology, and doubtless much remains to be done in this field. In Chapter III Dr. Edward W. Berry has given a brief discussion of what is known about disease among fossil plants but apparently the field has not been as intensively cultivated as it has been among recent plants, and that for obvious reasons.

EVIDENCES OF DISEASE AMONG FOSSIL PLANTS

That ancient plants, as well as animals, were subject to disease and injury of various types, may be seen by referring to Chapter III. Bacterial and fungus activity is known to have been in existence since the Devonian and was especially active during the Carboniferous. Probably evidences could be detected at much earlier horizons if petrified material of greater age were available for study. It is often difficult

[15] Synthesis of Paleontology and Medical History. Science, N. S., xlviii, no. 1251, 1918, 619–620.

[16] "An infectious disease . . . may be interpreted as the result of parasitism in which no mutual adaptation has taken place, and in which the invasion of the host by the micro-organism is marked by a struggle, the local and systemic manifestations of which constitute the disease." Hans Zinsser: Infection and Resistance, 2nd ed. 1918, 8.

[17] H. H. Whetzel: An Outline of the History of Phytopathology, Phila., 1918.

to decide whether the ravages of bacteria and fungi are pre- or post-mortem, and thus to discriminate between disease and decay. Conditions seem to have been especially favorable for mycological growths during the Coal Measures and it may be that this rapid growth played a part in the production of the early obvious lesions of disease seen from this period.

APPARENT IMMUNITY OF EARLY PALEOZOIC ANIMALS TO INFECTIOUS DISEASES

Present observations indicate that the animals of the earlier periods of the earth's history were free from disease, and even injuries are rarely found. Although indefinite lesions have been recorded on the shells of brachiopods, cephalopods and lamellibranchs, possibly in many cases resulting from injuries to the mantle, they seem to be the results of parasitic attacks rather than due to infection or other cause. There are abundant examples of healed lesions in the ancient shelled animals. Doubtless many more have been seen that were never recorded. A lesion often seen occurs on the hinge line of molluscs or on the delicate calcified brachial supports of the brachiopods.

Accidental injuries are seen in the reticulum of ancient glass sponges. Early pathological conditions, however, seem to be indicated by the interdependence of organic forms rather than by the actual lesions of disease. Parasitism of a pathogenic nature occurs only as early as the Devonian. All the evidences at hand thus point to the conclusion that early life was comparatively free of any associations or conditions which could be regarded as pathologic. Bacterial infections are unknown until the late Paleozoic. Although bacteria are among the oldest known forms of life, having been described from the Algonkian, Gallatin Formation of Montana (Fig. 1), they seem to have been active in the deposition of limestones,[18] together with the algae with which they were associated. Extensive studies on the bacteria and fungi of the Coal Measures and later periods of France especially have been made by Renault and Van Tieghem (1895–1900). A fairly complete list of their publications is given by Smith (1905) in his bibliography on "Bacteria in Ancient Times," and their results are fully discussed in Chapter IX of the present work.

[18] The activity of bacteria, especially the *Bacterium calcis*, in the formation of recent limestone deposits has been studied by G. Harold Drew: On the Precipitation of Calcium Carbonate in the Sea by Marine Bacteria, and on the Action of Denitrifying Bacteria in Tropical and Temperate Seas. Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, 1914, V, 7–45.

Few lesions due to either accident or infection have been made known among either the vertebrates or invertebrates of the earlier geological periods, prior to the Carboniferous. It is true that pathologic individuals of the brachiopod *Platystrophia* belonging to the *Ponderosa* subgroup are quite common[19] in the Arnheim beds (Richmond group of the Mississippian) of the Ohio Valley. They are large, globose, asymmetrical forms frequently with distorted beaks, and in some individuals there is a tendency toward a loss of the fold on one side. But these incidents are quite late in the Paleozoic. *Loxoplocus*[20] is an irregularly twisted Silurian snail with rather thicker walls than those of its normal *Loxonema* relatives, that should owe its abnormality to an increased amount of salts dissolved in the sea waters of Guelph time. Another phenomenon of a different nature that should also be mentioned here is the depauperization or diminution in size of all the members of a fauna. The members look like their normal relatives, are exactly the same in proportions of the shell parts and in ornamentation; but the individuals are from one half to one twentieth of the size of the normal. Such depauperized faunas are well exemplified by that of the pyrite layer which represents the western extension of the Tully limestone in New York; that of the Salem limestone of Bedford, Indiana, of Mississippian age; that of the Cason limestone of Silurian age near Batesville, Arkansas; and many others. The diminution in size may be due to crowding in a limited environment, to concentration of sea water, to excess of iron salts in solution, to excess of hydrogen sulphide, and to decrease of the temperature of the water, perhaps through chilling by influx of an Arctic current. Whatever the apparent cause of depauperization, the ultimate cause seems to be in every case a decrease in amount of available oxygen.

Another and different type of pathology is indicated in the clam *Venus tridacnoides* (Plates VI and VII) of the Miocene of Virginia. This species seems to be established on pathologic individuals or a pathologic race of another clam *Venus Rileyi*. The pathology is apparently brought about through the crumpling of the edge of the mantle, possibly because of the incursion of fresh water into the normal sea in which the *Rileyi* was living. It is of interest to note that in the Miocene of Maryland the species, *Venus Rileyi*, occurs in abundance in its normal form, indicating that the freshening of the sea water which

[19] Eula Davis McEwen: A Study of the Bachiopod Genus, Platystrophia. Proc. U. S. Natl. Museum, lvi, 1919, 396.

[20] Data furnished by Dr. Gilbert Van Ingen.

induced the pathology was localized in the vicinity of the York River, Virginia.

All of these conditions are of course suggestive of certain types of pathology, but one is impressed by the paucity of the record among the thousands of examples of normal forms which have been studied and described. The lack of knowledge may be due to several factors. The external stony skeleton of the early animals protected them more completely from traumatic influences, and the occasional specimens which show fracture of the shell indicate only severe trauma. Numerous observations have been made on callosities on the inside of the shells of brachiopods, where the shell had been broken in life and later repaired with the formation of callous lumps. Such evidences are at least as old as the middle of the Ordovician.[21] Injured crinoids with regenerated arms also indicate a certain type of injury and recovery therefrom, the regenerated arms often being double. A brachiopod shell with fracture and healed lesions is shown in Figure 3e.

While it seems possible that we are largely ignorant of pathology among ancient invertebrates yet it may well be that the invertebrate animals of the Proterozoic and Paleozoic, which were the predominant types of animal life during these periods, were free from disease which afflicted the hard parts, as are, in general, the invertebrates of today. It is true that many recent invertebrates are highly parasitized and are often subject to epidemics of disease. It appears probable, however, that vertebrates have been more liable to diseases which afflict the hard parts than have the invertebrates, either fossil or recent. This conclusion may be due to the fact that more is known about disease among vertebrate groups. This liability to pathological changes has increased with the passage of geological time.

REGENERATION

The results of severe traumatism, especially among certain of the invertebrates, are often seen to be interesting forms of regenerated parts. Since traumatic lesions of all kinds are a phase of pathology my purpose in mentioning regeneration here will be to discuss briefly the question of regeneration among fossil animals. A much more elaborate account might have been prepared and more examples of regeneration in fossil animals might have been mentioned but for the purpose of this book as an introduction to the study of ancient evidences of disease the following account will suffice. I acknowledge the aid of

[21] I owe these observations to Dr. Charles Schuchert.

Miss Mary Rathbun and Mr. Frank Springer for the materials in this section.

Regeneration among modern Crustacea is a matter which is commonly known, the regeneration often resulting in malformation due to new formation of the lost part in an altered form. This is most commonly seen in the case of claws and pincers, because these are the parts which are most commonly lost in fighting. Since these are the portions of the decapods most frequently fossilized, interesting examples of ancient regeneration are possible of determination among fossil forms. Since the tests of these creatures are so fragile the number of specimens preserved is necessarily limited and the association of parts is often lost.

Malformation among the Crustacea has been abundantly described among modern forms, especially by Faxon,[21a] who has discussed especially the deformed claws of the lobster and the blue crab. Herrick[21b] and Cole[21c] have likewise further discussed the question, but to mention other examples and especially the enormous literature of experimental work done on regeneration would lead us too far afield. There are in the U. S. National Museum various specimens similar to those described above but Miss Rathbun writes that she has never encountered any examples of regenerated parts among fossil decapods.

The fossil crinoids or sea lilies furnish many of our most obvious examples of regeneration and I have quoted from Mr. Frank Springer's "The Crinoidea Flexibilia," pp. 402–3, his discussion of this question. I also owe to his courtesy the figures shown in Figure 3b, c, and d.

> Among the numerous specimens of this species (*Taxocrinus colletti*) some interesting special cases have been observed. Among these are:—
>
> (3) Malformation. This is shown by figures 10a, b, c, of Plate LVII, where the specimen has apparently six rays, the left posterior radial being an axillary and supporting two equal series of primibrachs; there is accompanying confusion among the basals, only four of them being in the ring, while the fifth is superimposed at the posterior side, as shown in the diagram. Still more interesting than this is a remarkable case of:—
>
> (4) Recuperation (Pl. LVI, figs. 11a, b, c). In this case the entire crown except the infrabasals and one basal has been broken off and replaced by new growth; the stem and plates mentioned clearly belong to a much larger crinoid, and the one remaining basal tells very plainly what has happened. Here also are six rays, one directly following the old basal without any regard to its angular axillary face which remains exposed exteriorly; one opposite to it, and two each from axillary radials at each side; three greatly unequal new basals and two

[21a] On some crustacean deformities. Bull. Mus. Comp. Zool., viii, No. 13, 1881.
[21b] Symmetry in the big claws of the lobster. Science xxv, 275, 1907.
[21c] Description of an abnormal lobster cheliped. Biol. Bull., xviii, No. 5, 1910.

each from axillary radials at either side; three greatly unequal new basals are developed beneath these. This individual had only one basal left to build upon, and the recuperation of the entire crown from this indicates that the seat of vitality was lodged low down within the infrabasals. The structures can be well studied in the diagram, IIc, where the old plates are shaded and the new growth shown in outline.

Recuperation of more than a single ray in Paleozoic crinoids has not hitherto been recorded, but I am now able to report an interesting case of apparently habitual detachment of all the arms in life, and occasional regeneration, in the rather abundant species of the Cincinnati area described as *Heterocrinus juvenis* Hall (24th Report New York State Mus., 1872, pl. 5, figs. 9, 10; Meek in Paleontology of Ohio, vol. I, pl. I, figs 3a, b). This is now known to belong to the genus *Ohiocrinus*, having the arms heterotomous with lateral ramules springing from strong rami, instead of dichotomous as in the typical Heterocrinus. The species is usually found in good preservation, except that by far the greater number of specimens are minus the arms, as shown in Hall's figures 9 and 10 and Meek's figure 3, above cited. The break is almost invariably at the level of the tegmen, just above the first primibrach, and it includes the anal tube as well as the arms. This loss of the normal food-gathering apparatus was not immediately fatal, for in a large number of individuals the fractures were partially repaired, leaving the surfaces smoothly rounded; and the stumps of rays are often bent inward as if trying to close over the tegmen, as shown in Hall's figures. Efforts at recuperation were made, sometimes producing a new set of arms usually of a different size or color and more or less imperfect, and sometimes resulting only in the addition of a few dwarfed brachials.

This tendency to cast off the arms resulted in a remarkable dwarfing of the crown, which is usually no larger in diameter than the stem, while the latter, as compared with the stem of crinoids generally, appears relatively of enormous size. Among 195 specimens of this species in the collection before me 117 have lost their arms, leaving the fractured surfaces rounded, while 55 show more or less recuperation. Specimens with the arms in the normal condition, like Meek's figure 3a, are quite rare.

Similar occurrences are frequent among the recent Bourgueticrinidae. Danielson has described some of them in the Arctic species, *Bathycrinus* (*Blycrinus*) *carpenteri*, and *Doederlein* in species of *Bathycrinus* and *Rhizocrinus*. The species of these genera in which the loss and occasional regeneration of arms are chiefly observed all have the relatively very large stem and diminished crown seen in the fossil species above mentioned; and, as in that species, the separation of the arms seems to be a very common occurrence, leading to the suggestion by both these authors that it may have been a voluntary autotomy. Some of the instances of regeneration are very remarkable—one reported by Doederlein (Siboga, p. 6, pl. 5, fig. 3) being that of a stem which had lost the entire crown, but still had life enough to regenerate structures at the proximal end, which took the form not of calyx plates, but of radical cirri, thus producing the singular arrangement of a stem with a root at each end.

IMMUNITY IN MODERN INVERTEBRATES

The greater immunity of early Paleozoic animals to disease, based on the evidences of paleontological material, is probably not a true index to actual conditions. It is probably not safe to conclude from present-day conditions what the state of Paleozoic animals may have

been as regards disease. At any rate the paleontological evidences are not wholly substantiated by conditions found in modern forms. The immunity among Paleozoic invertebrates may be apparent, only based on insufficient data, or it may be the correct status of affairs. The conclusions of observations so far made point to the latter being true. Metchnikoff has called attention to the occurrence of epidemics of a severe nature among protozoa, such as diseases in *Amoebae* caused by the *Microsphaera* and the disease in *Actinophrys* attributed to fungi allied to the genus *Pythium*. Pasteur's studies on the *pêbrine* and *flâcherie* of the silkworms will be remembered as instances of severe epidemics in an invertebrate group. Molluscs, however, are apparently largely immune to infection. Since the molluscous animals formed such a large percentage of the preserved faunas of the early periods of the earth's history we may attribute our ignorance of the presence of disease to this factor, in part at least. The immunity of many intermediate hosts to infection is well known. The classical example of the mosquito-borne infections will suffice, although it is well known that insects of many kinds are subject to fatal diseases. Kowalevsky has discussed the anthrax of crickets and many other students have studied the problem. The entire question of immunity in its relation to all forms of extinct animals is of course a new and unsolved problem. But it seems certain that if the early animals were diseased, the ensuing pathology was of such a nature as to leave no impress upon the fossilized part; or else we have not yet learned to recognize these lesions.

THE ORIGIN OF DISEASE

Disease doubtless began with the inception of antagonism between two forms of life, and this may have occurred as early as the Archeozoic, and disease thus be as old as life itself. The evidences thus far seen point to a benign antagonism only late in the Paleozoic. If this is true the early faunas were free of disease. Phagocytosis began, without doubt, very early in the history of animal life. It is probable that the natural immunity of the early animals was sufficiently strong to resist the invasion by any pathogenic organisms in sufficient numbers to produce disease. The breaking down of this immunity may possibly be correlated with the development of senescence[22] among the

[22] The studies of Charles Emerson Beecher (1856–1904), an American paleontologist, upon evolutionary phases of the early fossil brachiopods and trilobites are especially important to a consideration of the question of race senescence and the extinction of animal groups. His papers have been collected into a volume: "Studies in Evolution," New York, 1901.

The entire subject of senescence in the recent lower animals is discussed by Child in "Senescence and Rejuvenescence" University of Chicago Press, 1915.

early races of animals, which reached a climax in the trilobites at about the time we find the early indications of disease among fossil animals. The breaking down of the immunity, due to the development of race senescence and the introduction of disease, doubtless was of great importance in the extinction of the trilobites, and other great groups of animals which have disappeared from the earth.

I do not intend to assert that senility or senescence is a disease, but that age weakens the organism and the race and allows the ingress of disease. Minot[23] has stated:

> Old age is not a disease and cannot be cured; it is an accumulation of changes which begins during earliest youth and continues throughout the entire life of the individual.

It may be said that the evidences of disease in past geological time are not confined to those races of animals which showed senescence. Paleontological indications of senescence (Fig. 3a) are the reduction in size, or its contrary, the loss of racial vigor, an external manifestation often being seen in the production of apparently useless spines as evidenced in many races of animals which have become reduced or extinct, such as the crinoids, trilobites, brachiopods, ammonites and among reptiles the Permian forms and the dinosaurs, many of which assumed bizarre forms. The tendency of many races of animals to acquire spinous and other useless excrescences of the hard parts shortly before the extinction of the group is noteworthy, and this tendency has been regarded by paleontologists as an indication of senescence. It was doubtless correlated with the introduction of disease.

A study of senescence in dogs and the relation of old age to disease, recently made by Goodpasture,[24] supports in an interesting manner this suggestion concerning certain factors in the origin of disease among the animals of past ages.

INCREASE OF DISEASE IN GEOLOGICAL TIME

It will be interesting to show in a graph (Figure 2) how, according to present evidences, disease has progressed during the geological history of the earth. The graph is, of course, tentative and is based on present knowledge. It may with the advance of knowledge be entirely changed.

[23] C. S. Minot: Introduction (p. x) to Translation of Metchnikoff's "Prolongation of Life" by P. Chalmers Mitchell, N. Y. 1912, 8°.

[24] E. W. Goodpasture: An Anatomical Study of Senescence in Dogs, with Especial Reference to the Relation of Cellular Changes of Age to Tumors. J. Med. Research, Bost., xxxviii, 127–190.

The twenty-five divisions on the base line a-d represent as many periods of the earth's history. The divisions on the vertical line d-b represent the approximate number of diseases present in each period, as indicated by the known fossil lesions. The time intervals in the graph are shown as of equal value, but the geological periods are not at all of equal duration, nor of equal character. At the point "a" we may say organic life is first known. It will be seen that the line a-b, representing the history of disease, follows a base level for the first twelve periods of the earth's history. Then the curve gradually rises until during the Cretaceous at "c" diseases and accidents—such as caries, osteoperiostitis, deforming arthritides, necroses, hyperostosis, osteophytes, osteomata, fractures, and many infective processes reached a maximum of development among the dinosaurs, mosasaurs, crocodiles, plesiosaurs and turtles. The curve suddenly and sharply descends from "c," since with the close of the Cretaceous and the sudden extinction of large groups of reptiles, the incidence of disease also decreased. It seems quite probable that many of the diseases which afflicted the dinosaurs and their associates became extinct with them.

The mammals of the Cretaceous and early Tertiary periods do not seem to have been so generally afflicted[25] with disease as were the preceding groups of giant reptiles[26] nor as were the later mammals. The ascending curve therefore is not so abrupt as one might expect.

[25] The following criticism of this statement, published originally in the Annals of Medical History, vol. 1, 1919, from Dr. W. D. Matthew in a letter dated May 20th, 1919, will give an entirely different viewpoint, though I fear my results are not to be regarded as "statistics":

"I have read your discussion of pathologic evolution with interest, but your statements do not appear to me to prove anything, for you fail to take into account the fact that fossils become rarer and less well preserved as you go back in geologic time, and consequently diseased conditions are less likely to be noted and less likely to be recognized and recorded. You would expect to find more recognizable diseased conditions among ten thousand well preserved Pleistocene fossil mammals than among one hundred fragmentary and poorly preserved Paleocene fossil mammals; or among a thousand fine specimens of Cretaceous dinosaurs than among a hundred Triassic dinosaurs rather poorly preserved. Other neglected factors are that such conditions are more likely to be noted and recorded in large than in small animals, and in rare fossils than in common ones. There is no way of eliminating these three factors, any one of which vitiates your statistics."

I had offered no statistics but simply attempted to show the manner in which diseases occurred among the known fossil remains. Dr. Matthews' remarks should, however, add caution to the acceptance of any results in paleopathology as final. I have not changed the graph for it seems after a lapse of years of study essentially correct.

[26] Dr. Matthew elsewhere remarks: "My judgment would be that injuries and diseases are neither more nor less common among Tertiary or Mesozoic vertebrates than among wild animals today." I have been unable to find any literature, save a few scattering notes, which bear on the diseases of modern wild animals so am in no position to make a comparison. Certainly the evidences known are very scanty for both groups.

Certain processes of disease seem to have been acquired by the mammals from preceding forms, or at least the same diseases are evident in the reptiles and mammals. The curve rises rapidly, however, and reaches the highest point at "b," indicating that disease is much more prevalent at the present time than ever before in the history of the world.

The geological development of disease has certain curious characteristics which parallel facts in the evolution of animals and plants. Huxley many years ago called attention to certain persistent types of animals which had existed almost unchanged from early geological periods down to the present time. Among the known diseases of geological antiquity a few can certainly be called persistent or primitive types which have remained unchanged since the close of the Paleozoic. Other diseases arose and became extinct.

According to present evidences disease is from the geological standpoint relatively recent in its origin and has afflicted the inhabitants of the earth for only the last one-quarter of the earth's history—that is, for the last 25,000,000 out of a possible 100,000,000 years. Future discoveries will doubtless modify our present conceptions, but the above outline is a summary of our knowledge of the rise and development of disease among animals.

TABLE OF GEOLOGICAL EVIDENCES

The table given below will show briefly the antiquity of pathological processes in geological history. The estimates of time are based on the relative thickness of the pre-Cambrian and post-Cambrian rocks, as given by Osborn (1917). The estimates of the duration of the geological periods vary greatly. The duration of the Proterozoic was as great probably as all post-Cambrian time, which has been estimated at 100,000,000 years. A study of radioactive substances gives estimates as high as 1,600,000,000 years for the duration of the Archeozoic, although Walcott estimated that only 70,000,000 years have elapsed since the beginning of sedimentation. Schuchert estimates the duration of geological time at 800,000,000 years. While authors vary greatly in their estimates they all agree that the duration of geological time has been very great, running into many millions of years. The estimates given in the first column are conservative. The table will show the relative antiquity of various pathological processes, whatever value may be assigned to the time estimates.

TABLE SHOWING GEOLOGICAL ANTIQUITY OF PATHOLOGICAL PROCESSES

Time	Eras	Geological Periods	Chief Animal Groups	Evidences of Pathology
3,000,000 to 10,000,000 years	Cenozoic	Quaternary	Age of Man	Abundant lesions on fossil and subfossil human remains
		Tertiary	Age of Mammals	Numerous diseases represented on animal remains from the deposits of the period
6,000,000 to 12,000,000 years	Mesozoic	Cretaceous	Age of Reptiles	Lesions on the bones of mosasaurs, dinosaurs, pleisosaurs, turtles, crocodiles, phytosaurs and other reptiles representing diseases similar to the modern forms of periostitis, hemangioma, necrosis, caries, pyorrhea alveolaris, arthritides, fracture with callus, pachyostosis, osteoma, opisthotonos and other lesions which cannot be interpreted.
		Comanchean		
		Jurassic		
		Triassic		
12,000,000 to 19,000,000 years	Paleozoic	Permian	Age of Amphibians	The lesions known represent dental caries, pyorrhea alveolaris, fracture, osteomyelitis, callus and parasitism. These periods witnessed the beginnings of disease. Bacteria and fungi were abundant.
		Pennsylvanian		
		Mississippian		
		Devonian	Age of Fishes	Few evidences of disease are known from these periods. Beginning of dependent life. Parasitism. Traumatisms.
		Silurian		
		Ordovician	Age of Invertebrates	
		Cambrian		
31,000,000 to 50,000,000 years	Proterozoic	Keweenawan	First known fossils	Bacteria (non-pathogenic)
		Animikian		
		Huronian		
		Algomian		
		Sudburian	No life known	
45,000,000 to 1,600,000,000 years	Archeozoic	Laurentian	No life known	
		Paleolaurentian		

DESCRIPTIONS OF FIGURES 1-4 AND PLATES I–VII ILLUSTRATING THE INTRODUCTION

FIGURE 1

The oldest known bacteria, designated as *Micrococcus* from the pre-Cambrian rocks of Montana, had no relation to disease. The chains figured here were discovered by Dr. Charles D. Walcott of the Smithsonian Institution, in association with the earliest plants and animals, in the very early stages of the earth's history. It has been suggested that these bacteria were of the type which cause the deposition of calcium from sea water. They are associated with algae which may be seen in the broad stripes running diagonally across the field. X 1100. Courtesy of Dr. Walcott.

FIGURE 1

FIGURES 2-3

Figure 2

A graph showing the relative frequency of disease in the different geological periods, based on the meager evidences at present available. Spaces on the base line represent divisions of geological time, although it should be noted that the periods of time are not of equal duration. The point "c" represents the apex of the large reptilian groups.

Figure 3

PALEOZOIC EXAMPLES OF PATHOLOGY

a. A large (nearly two feet long) Paleozoic spinose trilobite, *Terataspis grandis* Hall, showing in the exaggerated spines indications of racial senescence. (After Hall.)

b. Recuperated crown of a fossil crinoid, showing the stem nearly as large as the crown. The crown was broken off during life, leaving only infrabasals and one basal, the parts above those being restored by a new growth producing an irregular crown with three new, very unequal basal plates and four radials, two of which are axillary, thus giving six rays. (After Springer.)

c. Right anterior view, showing old basal with distal faces still exposed. X 2. (After Springer.)

d. Diagram showing form and arrangement of plates, infrabasals and basals. Specimens from Keokuk Group, Lower Carboniferous, Crawfordsville, Indiana.

e. Brachiopod shell with fracture at the point of the arrow. *Rafinesquina alternata* Emmons. Lorraine, Ordovician, Halls Creek, Warren County, Ohio. Courtesy of Dr. W. H. Twenhofel.

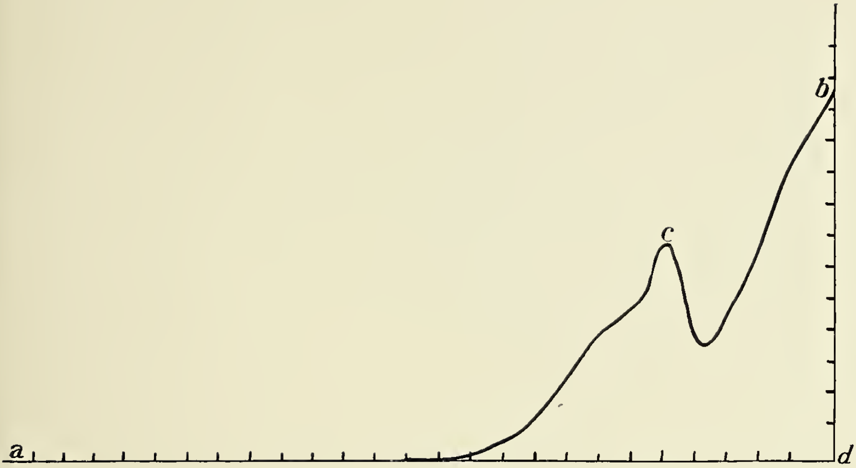


FIGURE 2

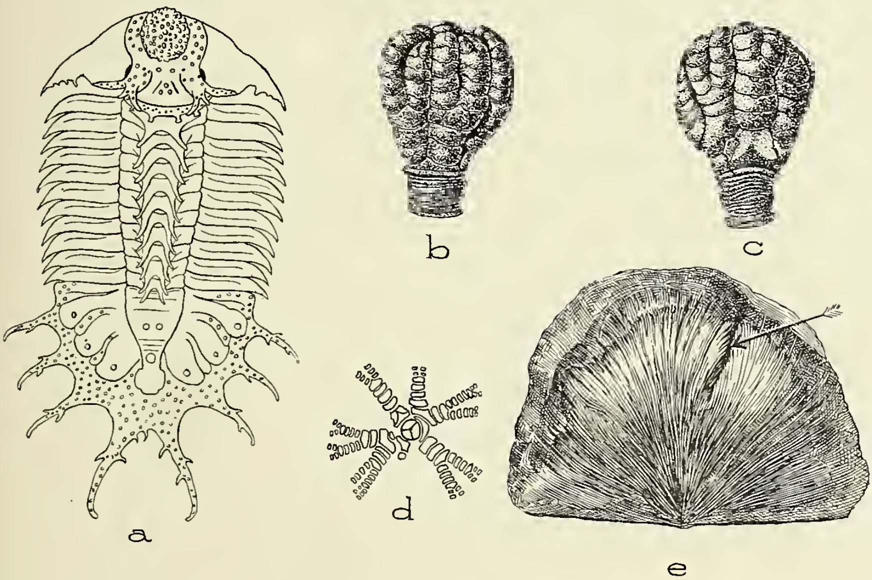


FIGURE 3

FIGURE 4

FIGURE 4

DIAGRAM ILLUSTRATING NORTH AMERICAN HISTORICAL GEOLOGY

The rivers on the earth have always carried mud, sand, and gravel to the sea, which, in settling, have spread out in layers over the sea bottoms. Remains of various forms of life, such as shells and bones, accumulated after death in these layers on the sea bottom, where the hard parts were preserved as fossils. In time, these sediments consolidated into hard rock and have been elevated above sea level.

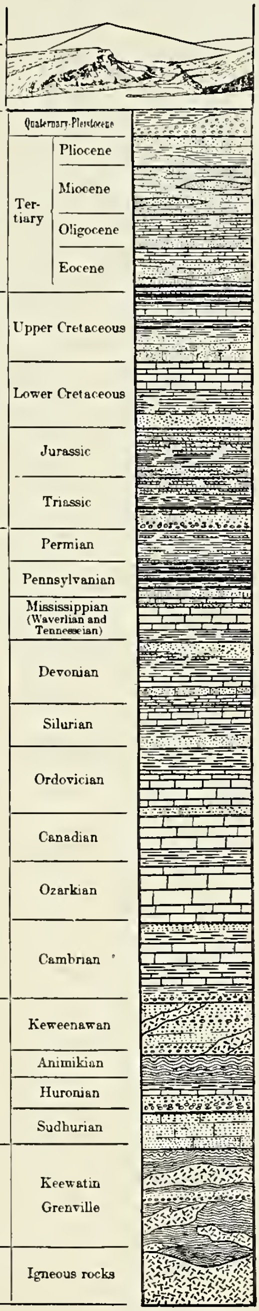
The geologist studies these ancient sea deposits, which now form a large part of the earth's surface, and from the nature of the sediments and from the life remains or fossils, that they contain, he is able to reconstruct much of the past history of the globe.

The rocks in the earth's crust give evidence also of the physical conditions under which they were formed, and apparently the physical processes, such as erosion and weathering, have not changed throughout time. The life on the globe, however, is constantly varying, owing to change of environment, and species after species sooner or later die out to be replaced by other forms of life. Rocks of similar age therefore contain similar species of fossils. Human history, which is measured in thousands of years, is but a small part of historical geology which necessarily extends back through many millions of years.

If all the sedimentary rocks of past ages had been accumulated in their greatest thickness at one place they would form a succession of strata over 40 miles in height. This succession, known as the geological column or time table, with the names of its subdivisions, the forms of life characterizing each, and the thickness and kinds of rock is shown in Figure 4.

(Courtesy of Dr. R. S. Bassler.)

DIAGRAMMATIC SECTION OF EARTH'S CRUST



ERAS OF GEOLOGIC TIME WITH CHARACTERISTIC LIFE			CHARACTERISTIC ROCKS WITH MAXIMUM THICKNESS
PSYCHOZOIC ERA (Recent) Age of man			Alluvial deposits in rivers, etc.
CENOZOIC ERA (Modern life) Age of mammals and modern plants	Quaternary-Pleistocene		Shale, sand, and gravel
	Tertiary	Pliocene	5,000 feet clay, shale, gravel, and sandstone
		Miocene	14,000 feet shales, sandstones, and limestone
		Oligocene	6,000 feet shales, sandstone, and limestone
		Eocene	8,000 feet limestone, sandstone, and coal
MESOZOIC ERA (Medieval life) Age of reptiles	Upper Cretaceous		20,000 feet sandstone, shale, limestone, and coal beds
	Lower Cretaceous		20,000 feet limestone, shale, and sandstone
	Jurassic		10,000 feet sandstone and shale
	Triassic		15,000 feet sandstone, shale, and coal beds
PALEOZOIC ERA (Ancient life) Age of higher invertebrate animals	Permian		7,000 feet sandstone and shale
	Pennsylvanian		10,000 feet sandstone, shale, and coal beds
	Mississippian (Waverlian and Tennesseian)		4,500 feet shale and limestone
	Devonian		12,000 feet limestone, sandstone, and shale
	Silurian		6,000 feet sandstone, shale, and limestone
	Ordovician		6,000 feet sandstone, limestone, and shale
	Canadian		4,000 feet limestone and shale
	Ozarkian		6,500 feet massive limestone
	Cambrian		18,000 feet quartzite, sandstone, shale, and limestone
PROTEROZOIC ERA (Primitive life) Age of primitive plants (algæ) and invertebrate animals	Keweenawan		30,000 feet conglomerate and sandstone with lava flows
	Animikian		14,000 feet banded slates and cherts with iron ore
	Huronian		10,000 feet glacial conglomerates, quartzite, and limestone
	Sudburian		20,000 feet of white quartzite
ARCHEOZOIC ERA (Primal life) Age of unicellular life	Keewatin Grenville		100,000 feet sedimentary schist and gneiss with lava flows; slates, conglomerates, and limestone
PRIMITIVE CRUST	Igneous rocks		Granite and other igneous rocks

FIGURE 4

PLATE I

PLATE I

MIDDLE CAMBRIAN ANNULATA

1–3. *Canadia setigera* Walcott. 4–7. *Canadia spinosa* Walcott. 8, 9. *Aysheaia pedunculata* Walcott.

From locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, west slope of ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

Plates I–V are introduced to show the normal marine fauna of Cambrian times, when so far as we now know there was no disease. These small creatures, shown herewith, may to be sure have been infected by sporozoans and hence have been diseased, but we have no way of knowing this. The fossil specimens indicate to us a healthy set of animals such as are commonly found in modern marine faunas. We suppose that disease did not exist at this time since it was millions of years later that a benign form of parasitism was introduced. There were no vertebrates of any kind when these animals were living back at the beginning of the known history of animal life.

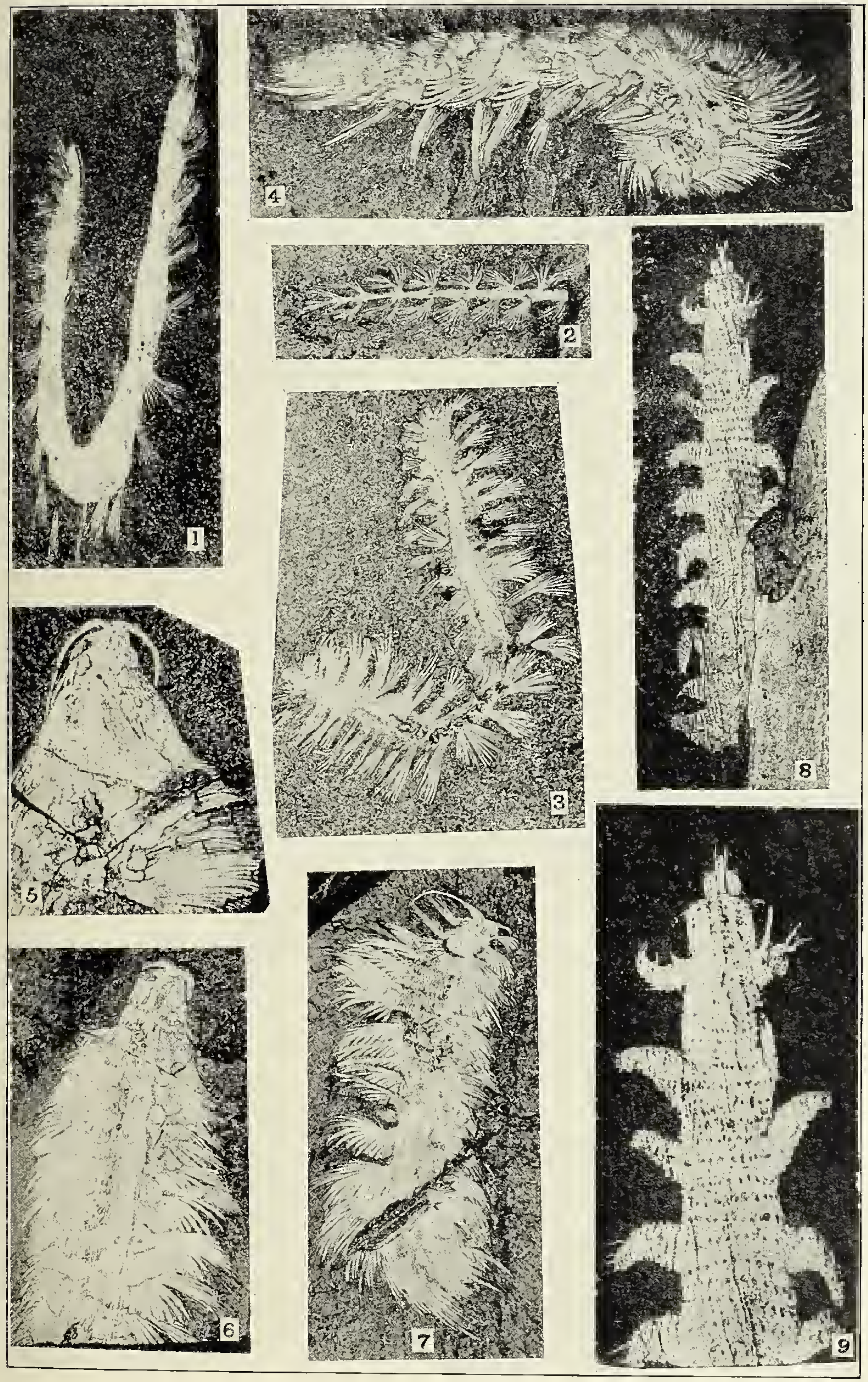


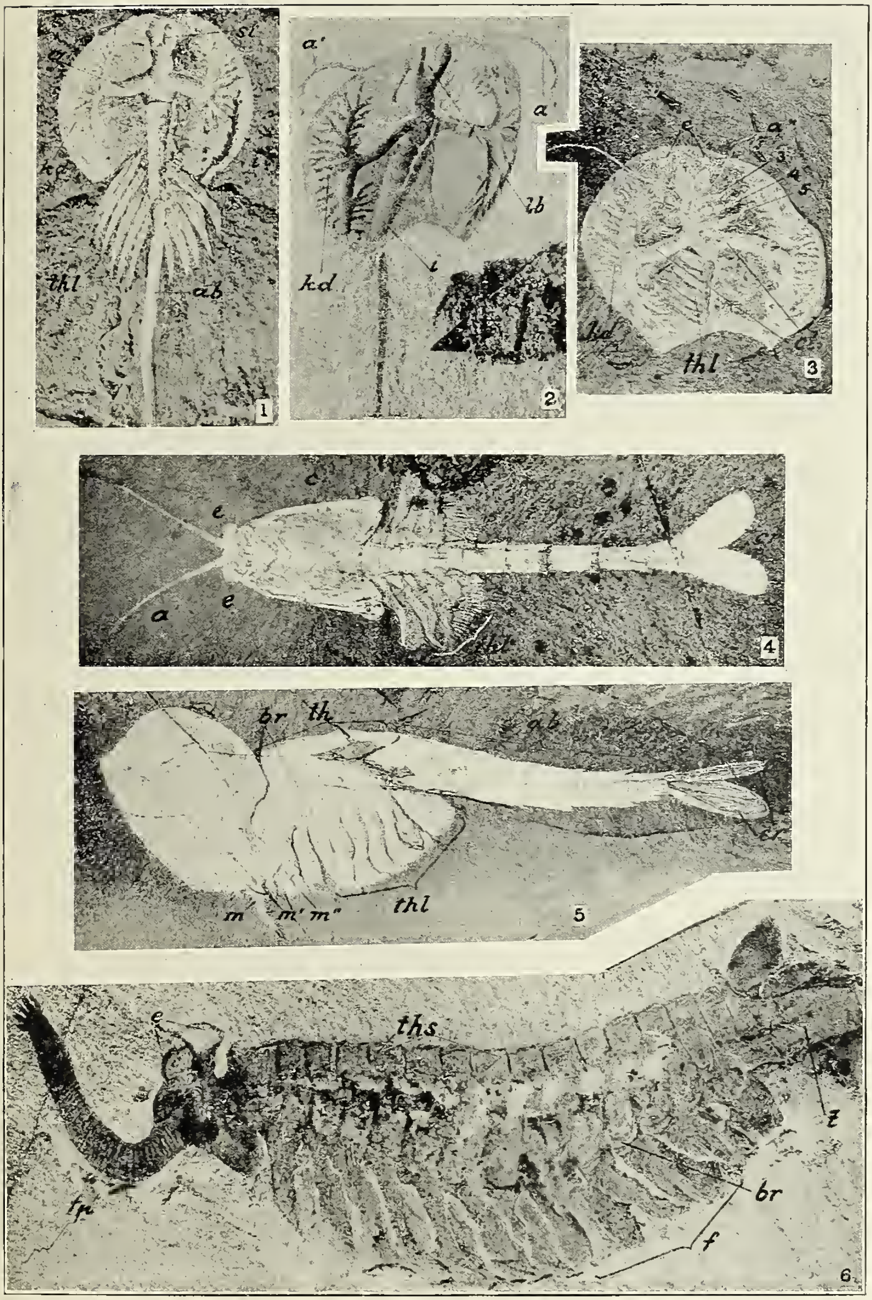
PLATE I

PLATE II

PLATE II

MIDDLE CAMBRIAN CRUSTACEANS

1–3. *Burgessia bella* Walcott: 4, 5. *Waptia fieldensis* Walcott; 6. *Opabinia regalis* Walcott. From Burgess Pass fossil quarry, near Field, British Columbia.



a
sl
kd
thl
ab
1
a'
a'
lb
i
kd
2
e
a
3
4
5
kd
thl
c
3
c
e
e
a
cr
thl
4
br
th
ab
cr
m
m'
m"
thl
5
e
ths
z
br
f
tp
6

Plate II

PLATE III

PLATE III

LOWER CAMBRIAN TRILOBITES

1. *Holmia ? macer* Walcott; 2–10. *Olenellus truemani* Walcott. Mahto formation; from Mumm Peak, 6 miles north of Robson Peak and northwest of Yellowhead Pass, in western Alberta.

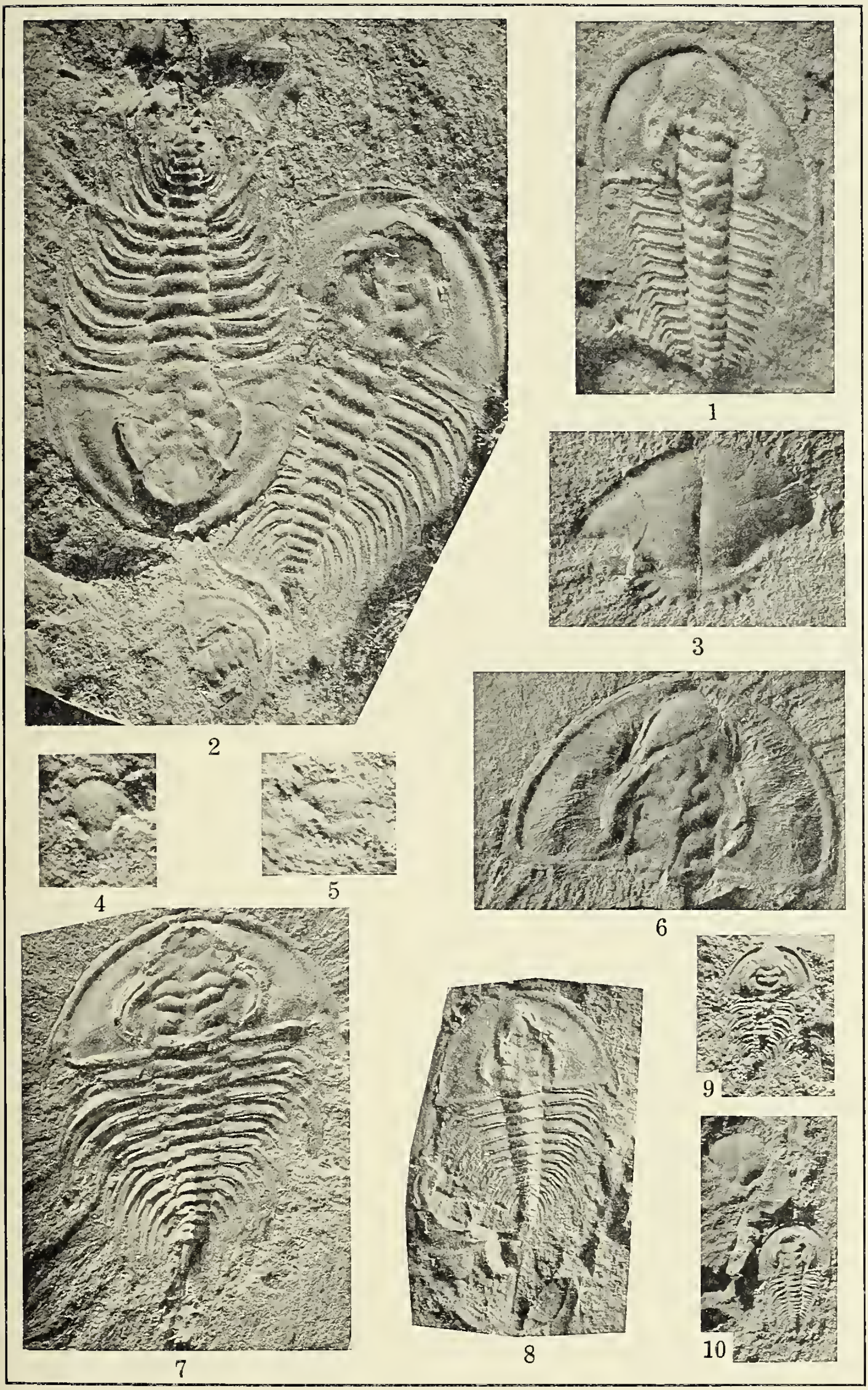


PLATE III

PLATE IV

PLATE IV

CAMBRIAN BRACHIOPODS

a = area; *cf* = cardinal muscle scar; *F* = foramen; *F′* = cast of foraminal tube; *h* = central muscle scar; *i* = transmedian muscle scar; *j* = anterior lateral muscle scar; *vs* = vascular sinus.

Obolus, Dicellomus, Lingulella, Acrothele, and other genera are represented from localities in the United States, Canada, Sweden, France, and China.

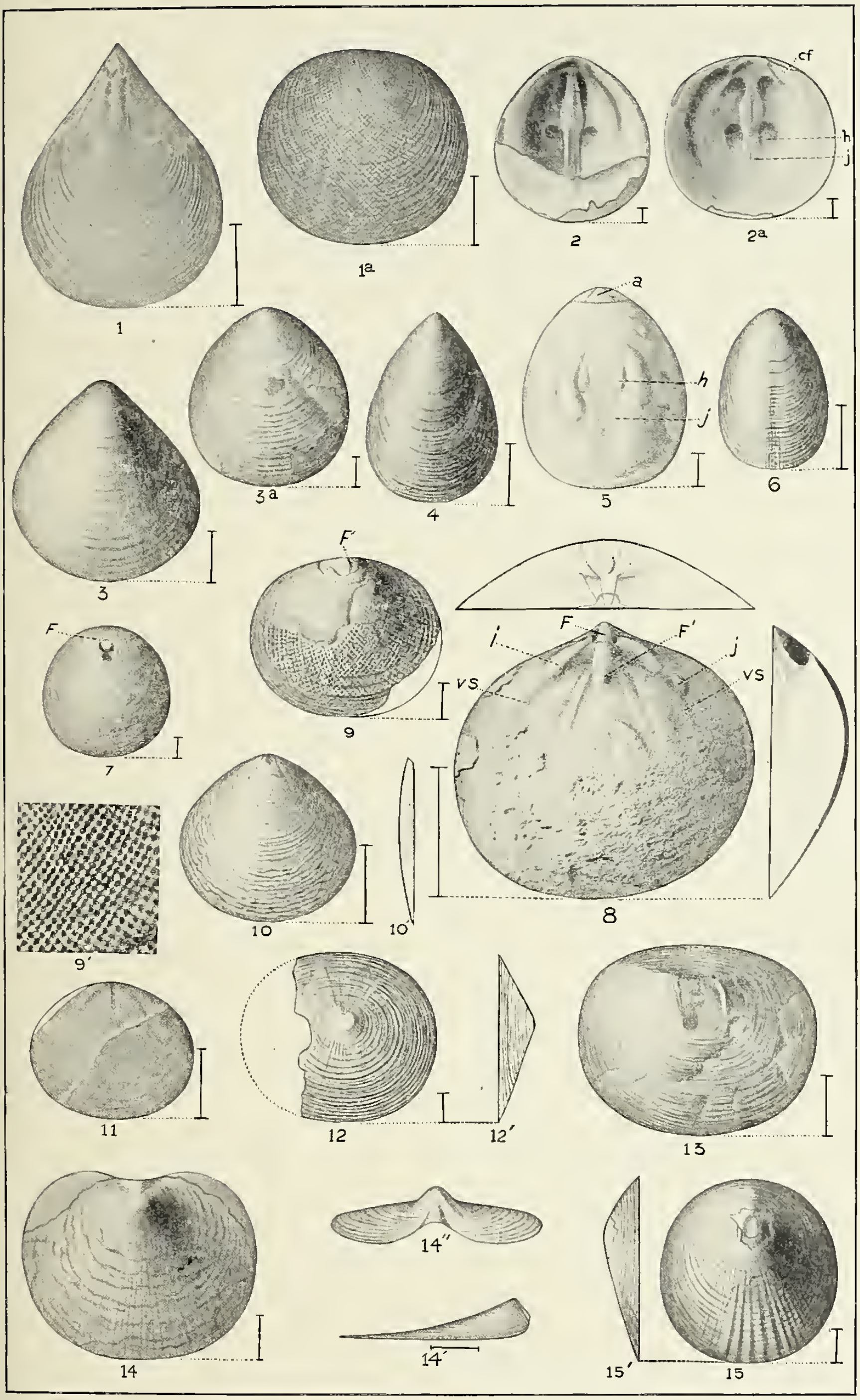

1
1a
2
2a
cf
h
j
3
3a
4
5
a
h
j
6
7
F
8
F
F'
i
j
VS
VS
9
F'
9'
10
10'
11
12
12'
13
14
14'
14"
15
15'

PLATE IV

PLATE V

PLATE V

MIDDLE CAMBRIAN MEDUSA AND HOLOTHURIAN

cr = central ring; *p* = digitate tentacle; *rc* = radial canals; *s* = stomach; *x* = four large lobes. 1, 2. *Peytoia nathorsti* Walcott. (Medusa, or jellyfish.) 3. *Eldonia ludwigi* Walcott. (Holothurian.)

From locality 35k, Middle Cambrian; Burgess shale member of the Stephen formation, west slope of ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

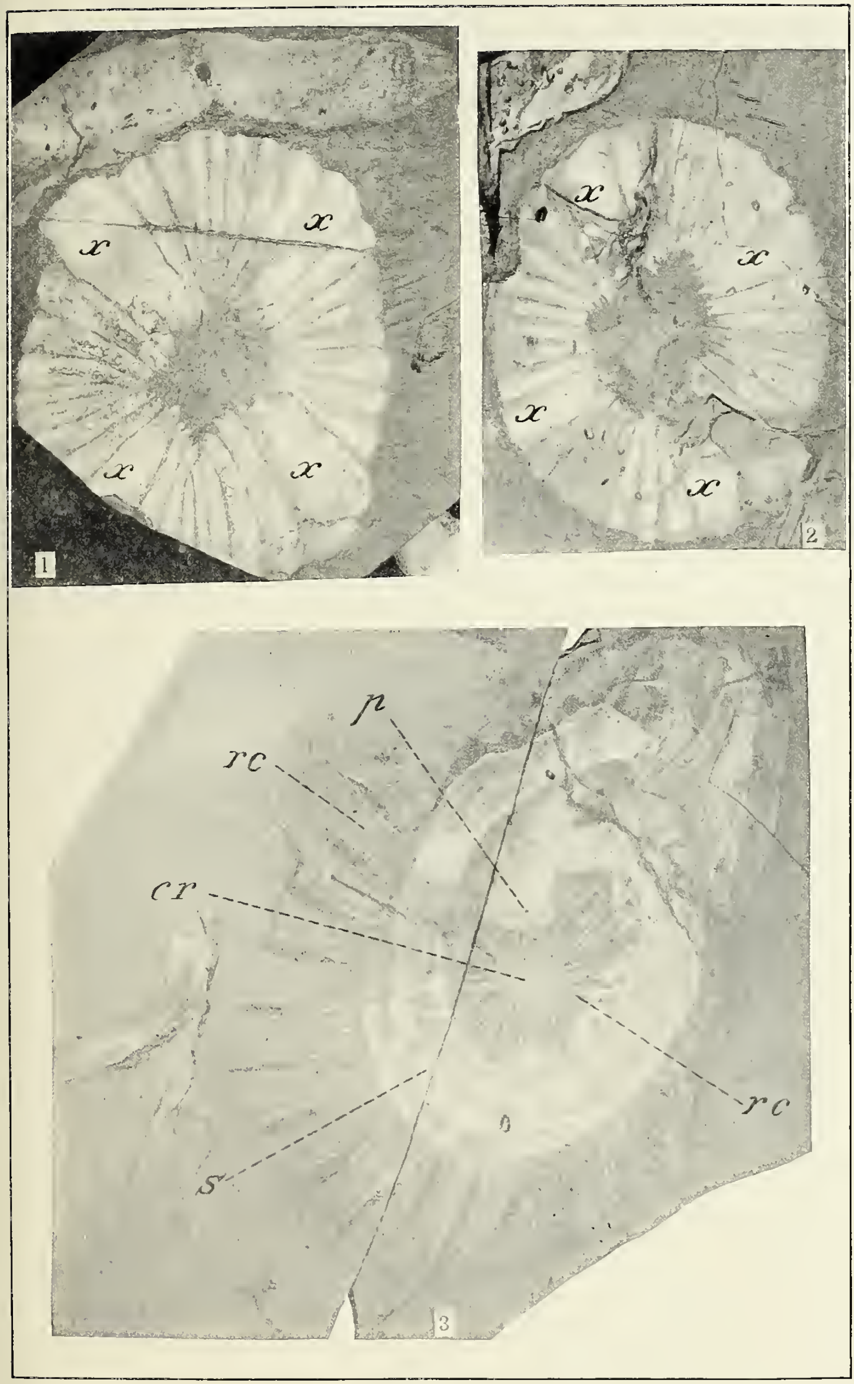


PLATE V

PLATE VI

PLATE VI

MIOCENE NORMAL AND PATHOLOGIC CLAMS

External and internal views of the right valves of the two types of clamshells known as (A) *Venus Rileyi*, which is supposed to be the normal form and is obtained from the Miocene deposits of Maryland, and (B) the so-called *Venus tridachnoides*, supposed to be the pathologic race of the previous species and is derived from the Miocene deposits of York River, Virginia, where an incursion of fresh water may have brought about the crumpling of the edge of the mantle. This would result in a disturbance in the metabolism of the individual clams, producing the enormous roughening of the exterior of the shell and the hypertrophy of the calcareous and chitinous material. The specific characters of the two types of shels are said to be identical.

To the left are shown sawn sections through the two right valves of (A) *Venus Rileyi* and (B) *Venus tridachnoides* indicating the degree of hypertrophy, the nature of which is shown in Plate VII.

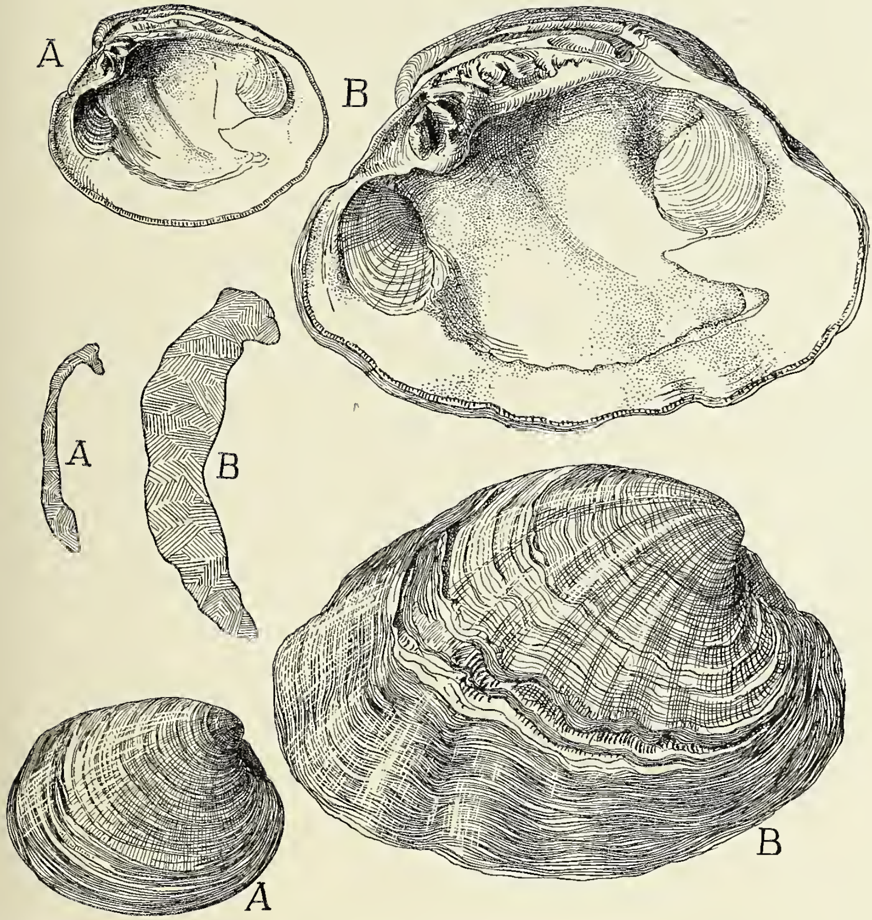


Plate VI

PLATE VII

PLATE VII

PHOTOMICROGRAPHS OF A NORMAL AND A PATHOLOGIC CLAM

a. The layers of the shell of *Venus mercenaria*, a recent clam shell from the coast of Cape Cod, Massachusetts, to show by comparison with "b" the relative thickness of the layers of nacre. The prismatic layer is still evident above in this shell, but it was not evident in the fossil. X 50.

b. The layers of the fossil shell, *Venus tridachnoides*, showing that the hypertrophy is a matter of increased thickness of the layers of nacre, on which fact its pathologic nature is assumed. If regarded as pathologic it must be of the more benign type, on the borderland of a diseased condition. X 50.

The micrometer measurements of the layers of the three species of *Venus* are as follows:

Venus mercenaria.	Innermost layer	80	microns
	Intermediate layer	75	"
	Layer adjacent to periostracum	140	"
Venus Rileyi.	Innermost layer	148	"
	Intermediate layer	78	"
	Layer adjacent to periostracum	240	"
Venus tridachnoides.	Innermost layer	262	"
	Intermediate layer	168	"
	Layer adjacent to periostracum	551	"

The same layer was chosen in each case for measurement so far as was practicable, but anyone who has attempted such measurement soon finds that his measurements are approximate only. They serve to show the nature of the hypertrophy in the pathologic clam.

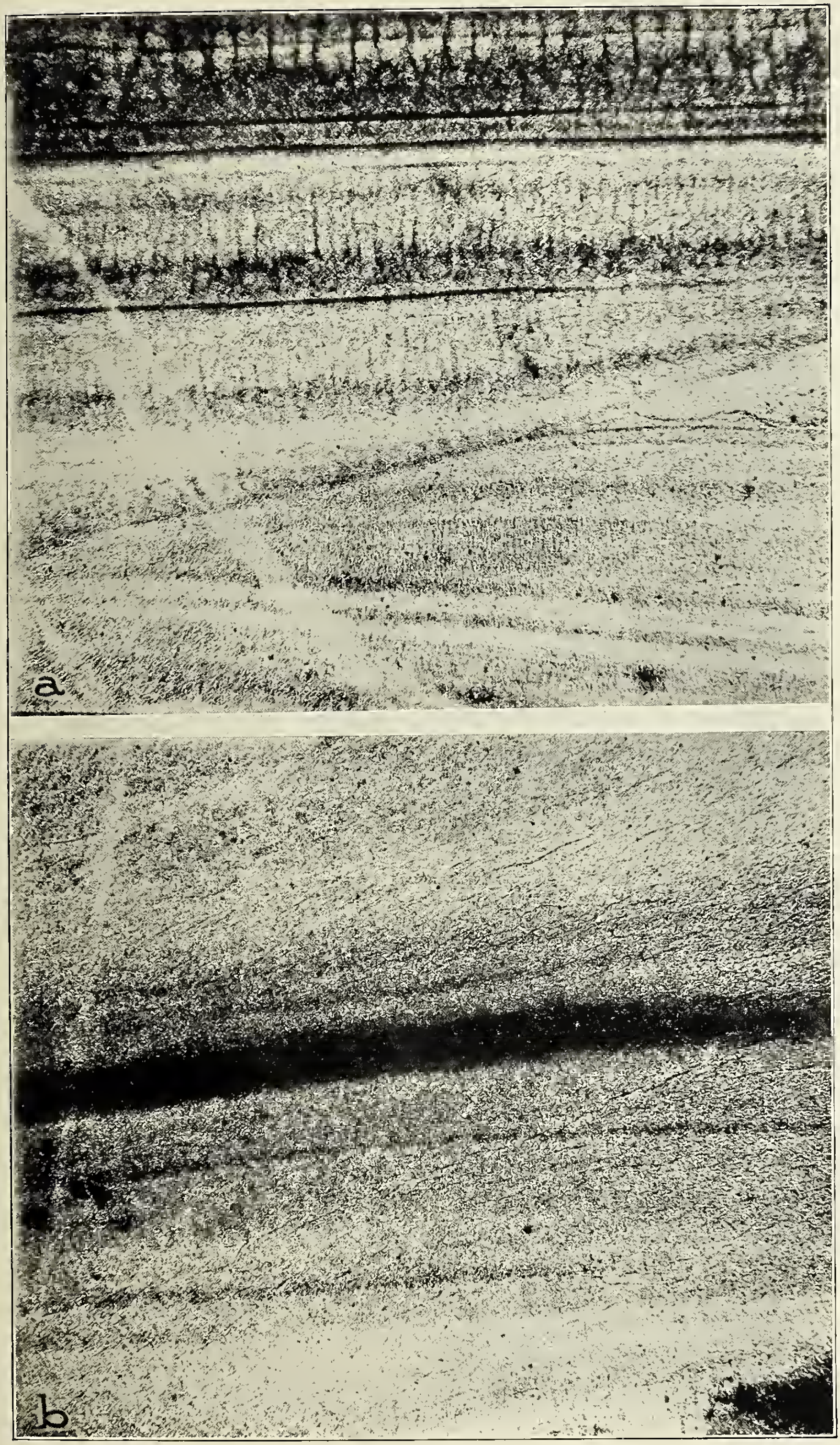


Plate VII

CHAPTER I

DEVELOPMENT OF PALEOPATHOLOGY

Historical account of studies on ancient diseases. Tabular review of literature dealing with Paleopathology. Nature of ancient diseases. Persistence of certain types of disease. Tabulation of the antiquity of certain pathological processes. Measurements of geological time. Descriptions of Figures 5-7 and Plates VIII-X illustrating Chapter I. Figures 5-7 and Plates VIII-X.

HISTORICAL ACCOUNT OF STUDIES ON ANCIENT DISEASES

The literature of vertebrate paleontology contains a number of incidental references, and a few detailed studies, on the diseased nature of the fossilized bones of fishes, reptiles, birds and mammals. These contributions will be reviewed in this chapter. The subject of ancient diseases has occasionally attracted the attention of men trained in the study of medicine and has resulted in a number of interesting contributions. Two such men were the surgeon von Walther and the pathologist Rudolf Virchow. Their contributions are discussed below.

The literature of archeology and anthropology has been drawn upon for data concerning the nature of ancient diseases and is especially referred to in the later pages of this work where the pathologic conditions of the early human races are discussed.

The studies on the pathology of ancient Egypt are only briefly referred to in this chapter, a fuller account being given in the discussion of the "Diseases of the Ancient Egyptians."

Pathological conditions on the fossils of bones of extinct animals were first recognized and described among the Pleistocene mammals, especially the cave mammals of Europe. These remains were the first to attract the attention of the early paleontologists and the relics found in them were for a long time supposed to be evidences of the universal flood which according to Hebrew tradition had destroyed all animal life. Dean Buckland (1784–1856), of Oxford, in 1824 especially defends this idea in his "Reliquiæ Diluvianæ," wherein he says (p. 42):

Thus the phenomena of this cave seem referable to a period immediately antecedent to the last inundation of the earth, and in which the world was inhabited by land animals, almost all bearing a generic and many a specific resemblance to those which now exist; but so completely has the violence of that tremendous convulsion

destroyed and remodelled the form of the antediluvian surface, that it is only in caverns that have been protected from its ravages that we may hope to find undisturbed evidences of events in the period immediately preceding it.

The earliest reference, in paleontological literature, to the pathological nature of fossil bones was by E. J. C. Esper (1742–1810), Professor at Erlangen, in 1774, as cited by Goldfuss. Esper described on the lower half of the femur of a cave bear (*Ursus spelaeus*),[1] what he regarded as an *osteosarcoma*. Mayer (1854), however, says that it appears merely to have been a fracture, with some callus and necrosis of the bone.

Goldfuss, early in the following century, says regarding the manner of life of the Pleistocene mammals:

> That these animals were predatory is evidenced by the fact that at times the molars have polished surfaces and the apices of the canines are often broken off. Also the pathological bones so far found are evidence that they were wounded in ferocious encounters or other accidents. Esper figures a pelvis which shows traces of a fracture which has healed with the formation of considerable callus. I possess a skull in which the right half of the occipital has been crushed and especially the tuberosity at the lamboid suture has been so compressed that there is a depression (compressed fracture) at this place and the tuberosity has been pushed toward the occipital foramen.

The skull of the hyena referred to above by Goldfuss was later described and figured by Cuvier[2] (1820), (Figure 6) who says regarding this specimen:

> This skull is very remarkable in that it exhibits a wound which the animal had received some time before death, for the injury was well healed. The specimen is from Gaylenreuth, and has been sent me by Soemmering. The skull is that of an old hyaena who had suffered a severe injury to its occipital crest, probably from an attack of one of the large lions or tigers which lived in the same vicinity and whose bones are found mingled with those of the hyaena in the same caverns.

Cuvier also described and figured a healed fracture of the femur of *Anoplotherium commune* (1820). As a rule, however, he paid scant attention to this important phase of paleontology.

[1] Samuel Thomas von Soemmering (1755–1830), Professor of anatomy and physiology at Mainz (1784–1797), one of the most energetic and progressive anatomists of Germany, also (1828) studied and described this femur.

[2] Georges-Leopold-Chretien-Frédéric-Dagobert, Baron de la Cuvier, a noted French zoologist, paleontologist and comparative anatomist, 1769–1832. He is often regarded as the founder of systematic paleontology, a distinction which he probably shares with Lamarck, Pallas, Camper and many other contemporary and preceding students of the subject. His most famous work in paleontology is: *Recherches sur les ossemens fossiles*, in 1821–23 in 5 volumes. This work constitutes the foundation of the modern study of extinct vertebrates, based on his studies of the ancient mammals of the Upper Eocene of Montmartre. His philosophical speculations concerning extinction and geological succession are now mere matters of history, not being acceptable to the modern student.

There are in the Hunterian Museum of the College of Physicians and Surgeons in London some bones from the cave animals of Oreston, England, which were described in the early years of the nineteenth century by William Clift (1823), who observes that the appearance of disease in fossil bones is of rare occurrence. Among the bones he described, however, he found two examples in the metacarpal and metatarsal bones of the bovine animals, showing upon their surface the effect of ossific inflammation. There were also marks of disease in the lower jaw of a young wolf, in which there is an abscess and considerable necrosis of the bone.

At about the same time, certain fossil bones attracted the attention of an eminent surgeon, (Figure 7) von Walther,[3] who described (1825) numerous fossil Pleistocene bones[3a] showing pathological lesions. This paper has been carefully reviewed by Mayer (1854), who also pays tribute to Walther's reputation as a surgeon. Von Walther was much impressed by the undoubted evidences of disease, thousands of years old, which he observed on eleven of the bones of the Pleistocene cave bears and cave lions, as seen and studied in the collections at Bonn. A right femur exhibited extensive necrosis, with widespread carious roughening of the bone. He observed also co-ossification of two dorsal vertebrae due to arthritic lesions; caries in the left mandibular ramus, especially extensive in the alveolar fossae and processes of the canine and molar teeth, resulting in extensive absorption of the processes. He described on another mandibular ramus a heavy thickening of the alveolar process associated with an extensive carious surface, and numerous osteophytes. A lumbar vertebra is widely necrosed by caries. Von Walther remarks:

> There is no doubt that the animal, to which this lumbar vertebra belonged, had suffered from tuberculous spondylitis, and that the disease was in its advanced third stage.

A left mandibular ramus shows an hypertrophied mental protuberance, associated with diseased incisors. The entire alveolar process is

[3] Philipp Franz von Walther (1781–1849) of Bonn was one of the most noted physicians of the early half of the nineteenth century. He worked energetically for the union of medicine and surgery and always kept in view in his practice a safe and sane viewpoint. He enriched surgery by the publication of numerous contributions as well as by a "System der Chirurgie" published in Breisgau in 1851, in five volumes. Von Walther is especially well known in connection with the publication of the *Journal für Chirurgie und Augenheilkunde* with von Graefe, from 1820 on. Albrecht von Graefe's Archiv is an outgrowth of the *Journal* established by von Walther and the elder von Graefe.

[3a] Von Walther's observations are discussed by Iwan Bloch: Ursprung der Syphilis, Abth. II, 320–321, 1911.

destroyed by caries in another ramus, only one molar process retaining its normal form, the remaining molars being loosened and the alveolar wall being entirely eaten away by infection. A mandible and a rib exhibit roughened carious portions. A radius is very light and its periosteal lamellae very thin with numerous exostoses especially well developed at the point of insertion of the biceps muscle, suggesting a condition similar to osteomalacia. A diseased cervical vertebra exhibits arthritic lesions similar to those of man. So that in these eleven described pathological bones the following lesions are evident: necrosis, ankylosis, caries, exostosis, production of new bony substance, hypertrophy, atrophy and arthritides.[3b]

The majority of the lesions described by von Walther are attributed to traumatic influences, but some of them, he says, are due to the weather, such as gout and other arthritic lesions. The concluding pages of this extremely interesting essay are devoted to a philosophical discussion of the nature and origin of disease. Von Walther concludes:

> We have no historical data to prove how old disease is nor when it first attacked the poor, sinful, human race. In every case disease is the fault of inheritance, and since they are visited upon the sons and daughters because of the sins of their fathers, they are true sins of inheritance.

The contributions of P. C. Schmerling (1835) to the early history of the human race were slow in receiving the credit due them. It was only after many years of arduous work that he succeeded in convincing his colleagues of the truth of his remarkable discovery of a paleolithic type of man in the caverns in the province of Liége. Even such a clear thinker and open minded man as Sir Charles Lyell (1867) was loath to accept the far-reaching discovery of Schmerling even after he had visited the caves in Belgium in which the discoveries were made. His work, however, has long since received its deserved place in the annals of science and his conclusions widely accepted. How he worked and sought new evidences is told by Lyell, Keith (1916), and Osborn (1916), as well as by many other writers on the antiquity of man.

Schmerling's discoveries were not confined to ancient human remains but he also discussed the significance of various lesions found on the fossil bones of extinct mammals which were mingled in the caverns with the remains of ancient man. His studies resulted in one of the

[3b] The specimens described by von Walther were discovered by Sack in 1824 in the caves near Iserlohn, Prussia and had been briefly noted by Nöggerath in: Kastner's Archiv für die gesamte Naturlehre, Bd. II, Heft 3, Nürnberg 1824, p. 324, who says: "So far as I am aware fossil bones showing pathological lesions have never before been described."

earliest memoirs on paleopathology (1835). He reviewed, in this contribution, a part of the pre-existing literature on paleopathology and spoke of the importance of the new science. He also added to the literature by describing various pathological lesions on the bones of Pleistocene mammals from the caves of Belgium. He published some figures of the lesions studied, which are commented upon by Mayer. Schmerling closes this early memoir on paleopathology by remarking:

> It is evident that the majority of the fossil bones exhibiting pathological lesions belong to the bear, and when one examines the kinds of affliction which have altered their structure, he is convinced that these pathological bones are for the most part due to mechanical, external causes. Fractures, caries, necroses are the diseases which are most common. Other bones, however, show lesions which do not, apparently, belong to these types of disease.

One of the most important of the early memoirs devoted to the study of paleopathology is that of Dr. Mayer (1854). In this memoir he reviews nearly all of the pre-existing literature on the subject and gives a brief description and a list of twenty-four bones of bears and lions, showing evidences of disease. He figures several of these in a beautiful lithographic plate. These figures have been copied and reproduced herewith. Plate VIII. They illustrate lesions in the skeleton of the cave bear (*Ursus spelaeus*) from the Pleistocene.

This memoir is especially useful in that it points out the majority of the pre-existing literature on the subject and gives, from a medical viewpoint, the value of the evidence paleontology may afford toward the history of disease. Mayer concludes:

> A general survey of the pathological lesions on the diseased bones of the cave bears described herewith shows that these lesions are the result of an inner constitutional weakness which has been more or less modified by external injurious influences which have called out this morbid diathesis, or else they are the results of traumata or other injurious processes. The fractures, caries, and injuries to the teeth are to be regarded as the results of blows, accidents, wounds received in the daily life of the animal. The healing power of nature was as potent, at this time, as in all later periods of animal creation, as is evidenced by the fact that fractures of the bones heal either neatly and completely, or else they become infected and heal with the formation of considerable callus and some necrosis and exostoses of the bone.

Apparently the first time the attention of a trained pathologist was called to the subject of paleopathology was when Virchow, in 1870, remarked to the Ethnological Society of Berlin, in connection with the discussion of the nature of the Pleistocene bones of the caves of Westphalia:

> I should like to remark in passing that while in Balve I saw a dorsal vertebra of a cave bear which has been greatly deformed by a bony mass due to spondylitis deformans.

This observation was the only published result of Virchow's[4] (Figure 7) interest in the subject until the publication of his paper in 1895, when he further discussed and figured the lesions on the bones of the Pleistocene animals inhabiting the caves of Prussia and surrounding regions. Since this essay constitutes the first, and thus far the only, attempt by a trained pathologist to discuss the nature of the diseased bones of fossil animals it has been thought worth while to give a translation of his essay, and to reproduce the figures (Plate VIII) which accompanied it.

Director Voss was kind enough, in his visit to the exhibition in Prague, to examine the diseased bones of the Moravian bears which are to be found in that city. Through the kindness of Dr. J. Matiegka and Mr. J. Knies I received several specimens of diseased bones from the diluvium of Sloup and Sosuska in Moravia.

The majority of the ursine bones I have been able to compare with the bones of recent bears in the anatomical collection and I was impressed by the enormous dimensions by which the ancient *Ursus spelaeus* differs from the modern bear.

With the exception of one vertebra from Sosuska all of the bones are altered by disease, most of them in the manner which I had first observed among Westphalian vertebrae of bears and which I had designated according to analogy with human pathology, as arthritis deformans. Later, as such conditions appeared very abundant, I have simply used the term "cave-gout."

I must, however, emphasize an essential difference from the arthritis deformans of human beings, as the excellent Moravian collection presented it to me. The disease in human beings especially attacks the joints. The surfaces of the joints become ulcerated and later undergo eburnation, while new bony masses proliferate freely on the circumference, at the end of the bones. This is not the case as a rule with the bones of the bears, in which the bulk of the proliferation rests much more upon the diaphyses or upon other apophyses. The vertebra from Sloup . . . has a large rough proliferation at the apex of one of the transverse processes, while the body of the bone and the other apophyses are entirely free from such growth (Fig. i) (Plate VIII). Only one phalanx (Fig. d-e) is irregularly bulged at its proximal end by huge osteophytes, but its joint surface is quite free, and in the interior a large medullary cavity has developed.

The other long bones display on the shaft diffuse distensions or irregularly knobby surfaces, which in human beings we should designate simply as hyper- or periostosis. These conditions are, however, nonexistent as a rule in human beings, although they are not an infrequent accompanying symptom of constitutional syphilis, being, in fact, so usual that a short time ago in a report on bone syphilis, I cited the bones of the bear as a parallel. These deformities, because of their wide distribution, point to a possibility that a constitutional disease is involved.

Only one radius shows evidences of local infection (Fig. b). This is a very large

[4] Rudolf Ludwig Karl Virchow, German Pathologist and Anthropologist, 1821–1902. He may justly be regarded as the founder of Paleopathology, although the term was not suggested until 1914 by Ruffer, 44 years after Virchow had made his initial contribution to the science. His observations on the pathology of *Pithecanthropus*, the Neanderthal man, the fossil bones of cave bears and his interest in evidences of pre-Columbian and prehistoric syphilis on ancient bones entitle him to a high place in the history of paleopathology. His high rank as a pathologist gives his observations on ancient pathology greater weight.

bone of about 200 mm. length, the joints of which are free. Almost the entire diaphysis is bulged out, so that the middle is most distended and the shaft appears spindle-shaped. Over a large part of this surface there is a carious roughening of 90 mm. length, which is so hollowed out in the middle that the compact layer of the bone cortex is bared. Around this ulcerous surface the bone is covered with strong, hard, although somewhat porous growths, which are drawn about the bone posteriorly, thus leaving one-third of the circumference free. Through these growths run wide, flat vascular spaces.

I have indicated in my paper on syphilis that the majority of evidences that have been interpreted in America to denote the existence of pre-Columbian syphilis, from the condition of many bones from "prehistoric" graves, concern no other deformities than the ones we find here among the cave bears. The explanation, however, in the case of the cave bears, is quite clear that primitive injuries are responsible, either wounds received in fighting or accidental traumata.

Among the specimens there is a rib (Fig. c, Plate VIII), the fractured zone being surrounded by periosteal callus.

In his paper on the history of syphilis Virchow compared more fully the above described lesions in the skeletons of cave bears with the bony lesions of syphilis, concluding with the statement:

But if we may assume with certainty that the bears of past ages had no specific infection and nevertheless suffered such diseases, we must also concede the possibility that in the case of ancient man a similar element entered into consideration, as with the bears, and that this sort of hypertrophy and deformation and this form of caries and hyperostosis need not arouse the suspicion of syphilis.

Virchow thus maintained that the *caries sicca* of prehistoric and pre-Columbian bones was not true syphilis but either identical with the arthritis deformans (cave gout) of old cave bears, or else caused by plants and insects, which would eliminate the question of prehistoric syphilis in Europe.

There are a number of other discussions of the pathological conditions of Pleistocene vertebrates but sufficient has been said in the preceding pages to show the trend of the studies. Naturally as our knowledge of ancient life developed the pathological conditions of ancient animal remains were noted, although nothing of importance appeared until the opening of the twentieth century.

Hatcher made one of the first observations in America on the diseased state of fossil reptilian bones, when in describing the osteology of one of the gigantic dinosaurs, *Diplodocus*, he remarks:

Caudals two and three are co-ossified (pathologically) by their centra. In No. 94 caudals seventeen and eighteen are similarly united. (Fig. a, Plate X.)

A species of dog from the Oligocene, *Daphenus felinus*, was also noted by Hatcher (1901) to possess on the internal side of each radius a "remarkable exostosis." He says:

On the inner side at the distal end of either radius there is a considerable growth of diseased bone, or exostosis mentioned above. They are remarkably similar on either side.

Mr. E. S. Riggs has called the writer's attention to a similar, apparently pathological, lesion on the limbs of a small carnivore from the Miocene of Nebraska, preserved in the Field Museum of Natural History.

Schlosser (1909) has written a very interesting account of the geology of the caves of Kufstein and their contents, with an account of his exploration and results of his discoveries of the remains of human and animal forms. Among these remains he found several diseased bones, which, however, do not differ essentially from those described above by Virchow. The pathological material, he says, is fairly abundant, most of them representing cave bears. (Plate VIII.)

Additional interesting evidences of disease among the Pleistocene mammals of Austria are suggested by the discoveries mentioned by Professor O. Abel, in a letter under date of April 21st, 1922. I quote the following account:

Mit aufrichtigem Interesse habe ich Ihrem Briefe entnommen, dass Sie eine Studie ueber Paläopathologie fertig gestellt haben. Ich erwarte diese Arbeit mit grösster Spannung und zwar aus folgenden Gründen. Seit dem Herbste 1920 sind wir mit der Ausgrabung der "Drachenhöhle" in Steiermark beschäftigt, die zum Zwecke der Gewinnung von fossilem Guano (den ich wegen seiner Herkunft "Chiropterit" genannt haben) vom Staate in die Wege geleitet worden ist; da wir ja infolge der elenden Finanzen nicht in der Lage sind, ausländischen Kunstdünger, Salpeter etc. für unsere Felder zu beziehen, so müssen wir nach solcher Aushilfe schreiten, wenn unsere Felder etwas tragen sollen, denn der Viehstand ist zu gering. Diese Ausgrabungen haben uns nun in die Lage gebracht, eine grosse Menge fossiler Reste aufzusammeln; ich habe die Oberaufsicht über diese Aufsammlungen, die in meinem Institute zusammenlaufen. Unter den zahlreichen zum grossen Teile hochinteressanten Funden eiszeitlicher Säugetiere und menschlicher Kulturreste aus der Moustérienzeit sind nun sehr viele pathologische Knochen, Schädel und Zähne, deren Bearbeitung ich für eine in Aussicht genommene Monographie, für welche ich Geldmittel sammle, vorbereite. Es liegen nicht nur von Ursus spelaeus sehr zahlreiche pathologische Fälle, daunter viele traumatische Erscheinungen, vor, sondern auch von Felis spelaea und, was sehr sonderbar ist, auch an Resten des Steinbocks, der ja gewiss kein Höhlenbewohner war und dessen Knochenkrankheiten daher auch nicht mit dem Leben in Höhlen in Verbindung gebracht werden können. Ein besonders interessanter Fall ist einer von Myositis ossificans an der Unterarmknochen eines Höhlenbären, eine Krankheit, die erst während des Krieges genauer studiert worden ist und eine Verknöckerung von Muskeln und Sehnen zeigt. Eine sehr grosse Zahl pathologischer Fälle betrifft das Gebiss und ich glaube dass noch nie so viele pathologische Fälle in einer einzigen Fauna angetroffen worden sind.

An early indication of giantism as seen in the hypertrophied skeleton of an extinct animal was described by Volz (1902) in a primitive

plesiosaur, *Proneusticosaurus*, from the Lias of Silesia. This condition (Plate X, b) (Abel, 1912) has been called *pachyostosis*, and a diagnosis of a diseased condition is made with the caution that the enlargement of the bones might be due to the supporting of some heavy armor. However, no armor is known in either the plesiosaurs or nothosaurs, so this may be fairly taken as an indication of giantism, millions of years ago.

The effect of an amputation on the leg of a giant turtle (Plate IX, c) is described by Wieland (1909) after studying the skeleton of *Archelon ischyros*, from the Cretaceous of South Dakota, as follows:

> On the right side, the femur is also present, with the proximal two-thirds of both tibia and fibula, which end in obliquely bitten off but healed surfaces. Both the femur and those mutilated elements are lighter and several centimeters shorter than the corresponding bones of the left side. In short, the evidence is conclusive and unmistakable that this animal had its right flipper bitten off when still young, and that as a result of this injury the remaining portion of the flipper was more or less arrested in growth by disuse. Such accidents are now and then noted in fossils.

Even the heavily armored and gigantic three-horned dinosaurs (Plate IX, a) of the Upper Cretaceous were subjected to injury and disease as indicated by Lull (1907) in describing the skull of *Triceratops serratus* from Wyoming, where he says:

> The right frontal is pierced at its posterior border by a large foramen, the posterior border of which is formed by the postfrontal. This foramen is absent on the opposite side, and it is probably pathologic.

The skull also exhibits a broken and healed right ramus of the jaw, and a broken and healed distal tip of the right horn core (Fig. a, Plate IX).

Other and more extensive injuries to the dinosaurs have been described by Gilmore (1912) among the skeletons of which he found in the U. S. National Museum, a scapula of *Allosaurus fragilis* which had been

> injured in life and the subsequent healing produced great deformation of the bone. This pathologic condition caused a widening of the blade that would be entirely misleading as to its true form had not the opposite scapula been present.

A full discussion of the injured ilium of Camptosaurus is given in Chapter VII under "Necrosis," where an illustration of the lesion is also to be found.

A curiously deformed phalanx of a camel (Fig. b, Plate IX) from the Pleistocene of Texas is described by Troxell (1915):

> Much has been said about the effect of diseases in causing the extermination of races. The interesting pathologic phalanx (Fig. b) is probably a result of exostosis

or uncontrolled deposition of bony material. The bone was not broken because it shows the same length as the normal one of the same size. Possibly the disease which caused the death of the individual also contributed to the destruction of the species.

Osborn described (1895) and figured the skeleton of an early ungulate, *Titanoterium robustum*, showing a fractured and healed rib of the right side. A photograph of this skeleton and a detailed picture of the callus is given elsewhere (Plate XX).

The most extensive account, and one which may be regarded as a résumé, is given by Abel (1912) under the heading "Traces of Fights" and "Bone Pathology." The following is a free translation of Abel's discussion:

Among the males of living mammals, ferocious encounters often take place for the female, and the female herself is often injured. Similar encounters are indicated among the fossil mammals and reptiles, and it is especially evident among the cave bears. In some of these animals, however, it is not always certain whether the lesions are due to these causes or to injuries inflicted by the early cave men. Such wounds are frequently present and are often nicely healed with a small amount of callus. Healed fractures are found in the snouts of Tertiary toothed whales from the upper Miocene of Antwerp. These clearly indicate that the broken bones had healed during life.

Similar healed fractures have been observed in a Liassic ichthyosaur, and in a mosasaur, *Plioplatecarpus Marshi*, from the Cretaceous of Belgium, there are several ribs which have been broken and healed during life. A specimen of *Mosasaurus giganteus* in the Museum at Brussels shows a right mandibular ramus which has been broken and healed.

It is evident that the injured skull of *Mylodon robustus*, described by Owen in 1842 is to be regarded as a healed injury which the animal had suffered, possibly during the pairing season, or by the fall of a tree. There were no creatures living in South America at that time sufficiently large to have inflicted the wound on the huge gravigrade. It is hardly probable that this wound could have been inflicted by the saber toothed tiger. The healing of this wound is an interesting indication of the amount of resistance which these huge animals possessed.

One of the most interesting types of injuries which has resulted in a periosteal exostosis is that found on the ancient soltaire (*Pezophaps solitaria*), a bird whose bones are found abundantly in a fossil and subfossil condition on the island of Rodriguez near Mauritius. The zoological museum at Cambridge, England, possesses great numbers of more less complete skeletons of this remarkable bird and the lesions have been described in full by Newton.

Rickets has been observed in apes from the Egyptian mummy graves, but this disease has not yet been clearly observed among fossil vertebrates, although Virchow said that the shortened ulna of the Neanderthal man was due to rickets.

Fossil bones often show certain changes in form which are to be regarded as examples of pachyostosis. These enlargements may be regarded as of functional importance as in the support of a heavy dermal armor.

Hypertrophy is also quite evident in a primitive sirenian, *Eotherium aegyptiacum* from the middle Eocene of Egypt, the anterior portion of the thorax and scapula are enlarged. In *Eosiren libyca* the posterior ribs and vertebrae are enlarged.

Hyptertrophy is also evident in *Pachycanthus suessi*, an early whale described by Brandt. Pachyostosis is also seen in a plesiosaur, and in a fossil fish.

Diseases of the mandible due to fistulae are of rare occurrence, but such a case is evident in the skull of *Eosiren* from Egypt which shows a dental fistula which has produced an extensive necrosis.

Caries of the teeth is often observed in the cave bears and it has otherwise been seen in a mosasaur, and in a Pleistocene mastodon.

Skeletons of ancient animals which show extensive ravages of disease are rarely found but Auer (1909) has discussed the paleontology of a crocodile (Plate X, c, d) from the Oxford Clay (Jurassic) of England and has shown the presence of numerous changes due to disease. The focus of infection seems to have been in the pelvis and from there spread by metastasis to other parts of the body involving the left femur, the sacral vertebrae and the palate. This is one of the few instances in which disease, in ancient time, has threatened the life of the individual. We cannot doubt that the crocodile died from the severe infection evidenced on the skeleton. Since this is the most serious pathological condition thus far described I consider it important to quote the exact words Auer used in describing the condition; which he gave under the heading:

PATHOLOGISCHE ERSCHEINUNGEN BEI METRIORHYNCHUS CFR. MORELI DESL.

Von besonderem Interesse ist bei den vorliegenden Objekt das Auftreten von pathologischen Erscheinungen, wie sie bei diesen robusten Tieren selten zur Beobachtung gelangen. Diese Erscheinungen machen sich besonders an den Palatina, an den beiden Femora und an dem einzigen erhaltenen Wirbel, einem Sakralwirbel, geltend und äussern sich an manchen Stellen der genannten Knochen in einer Reduktion, an anderen in einer eigentümlichen Wucherung der Knochensubstanz.

Auf der Mitte der Unterseite der Palatina is eine Stelle in sonderbaren Weise differenziert durch ein Art von Skulptur, die aus regellosen Wülsten, Löchern und Grübchen besteht, ein Verhalten, das sonst bei Krokodilen nicht angetroffen wird, und das ohne Zweifel im Zusammenhang steht mit den pathogenen Veränderungen, welche die gleich zu besprechenden Knochen zeigen.

Das rechte Femur ist seiner Form nach normal gebaut, zeigt aber unterhalb des Caput femoris eine eigentümliche Corrosion, und am distalen Ende ist der Condylus internus reduziert.

Das linke Femur weicht in seiner Gestalt vom normalen Typus ganz wesentlich ab: der Gelenkkopf hat eine bedeutende Schrumpfung erlitten, und die ehemals kugelige Gelenkfläche ist deformiert. Unterhalb des Gelenkkopfes zeigt der Oberschenkelknochen einen anomal geringen Durchmesser, und auf der Externseite des Knochens erhebt sich eine Leiste. An der Stelle, wo sich der sonst unbedeutende Trochanter femoris befindet, hat eine beträchltiche Wucherung der Knochensubstanz stattgefunden, die eine starke Verdickung des Knochens herbeiführte. An dieser Stelle ist der Knochen sehr unregelmässig gestaltet: es findet sich hier eine Menge von grösseren und kleineren Löchern und Grübchen. Die Diaphyse des

linken Femurs ist dicker als die des rechten und dafür nicht so breit. Zum Vergleich mögen folgende Massangaben dienen:

	rechts	links
Breite des Femurs 5 cm. unterhalb des Gelenkkopfes...........	2,3 cm	4,4 cm
Dicke des Femurs 5 cm. unterhalb des Gelenkopfes............	2,3 cm	3,6 cm
Breite 14 cm unterhalb des Gelenkkopfes....................	4,5 cm	4,1 cm
Dicke 14 cm unterhalb des Gelenkkopfes.....................	2,1 cm	3,6 cm
Breite 17 cm unterhalb des Gelenkkopfes....................	4,2 cm	3,8 cm
Dicke 17 cm unterhalb des Gelenkkopfes.....................	2,1 cm	2,8 cm

Gegen das distale Gelenkende zu wird der Knochen wieder rauher; die Gelenkflächen für die Tibia und Fibula sind verdreht und ganz verkrüppelt. Zwischen den beiden Condylen befindet sich ein tiefes Loch. Die Länge der beiden Femora ist so ziemlich gleich und beträgt 32,5 cm.

Auch der Sakralwirbel weist bedeutende Veränderungen pathogener Natur auf: der Wirbelkörper ist beträchtlich verdickt, an der Aussenseite unregelmässig geraut und mit zahlreichen, ziemlich tiefen Löchern bedeckt. Der Dornfortsatz mit den Zygapophysen und ein Sakralfortsatz sind abgebrochen. Der mächtig verdickte Wirbelkörper steht in seltsamen Gegensatz zu dem ausserordentlich schwachen, nach unten gebogenen Processus sacralis. Auf einer Seite ist die Endfläche des Wirbels erhalten, und zwar die, welche sich an den anderen Sakralwirbel anlegte, wie aus ihrer flachen Beschaffenheit hervorgeht. Von der anderen Endfläche aus ist der Wirbelkörper vollständig ausgehöhlt.

TABULAR REVIEW OF LITERATURE DEALING WITH PALEOPATHOLOGY

Date	Author	Animals Afflicted	Diseases	Geological Age Locality
1774	Esper	Cave-bear	Osteosarcoma (?)	Pleistocene Germany
1810	Goldfuss	Hyaena	Fracture	Pleistocene Gaylenreuth
1820	Cuvier	Hyaena	Fracture	Pleistocene
1820	Cuvier	Anoplotherium	Fracture	Oligocene
1823	Clift	Bovine animal	Ossific inflammation	Pleistocene England
1825	Walther	Cave-bear; cave-lion	Spondylitis deformans, caries, pyorrhea, exostoses, tuberculosis.	Pleistocene Germany
1828	Soemmering	Hyaena	Fracture	Pleistocene
1835	Schmerling	Cave-bears	Various	
1842	Owen	Mylodon (ground sloth)	Fracture, necroses	Pleistocene Argentine
1854	Mayer	Cave-bear, cave-lion	Spondylitis deformans, caries, fracture and callus, necrosis	Pleistocene Bonn
1858	Schaafhausen	Paleolithic man	Fracture, caries (?)	Pleistocene Neanderthal
1870	Newton and Parker	Birds	Osteoperiostitis	Pleistocene Rodriguez

Date	Author	Animals Afflicted	Diseases	Geological Age Locality
1870	Virchow	Cave-bears	Spondylitis deformans	Pleistocene Westphalia
1880	Etheridge	Crinoids	Parasitism	Carboniferous England
1881	Langdon	Pre-Columbian Indians of N. A.	Traumatism	Recent
1881	Le Baron	Neolithic man of Europe	Fracture and callus; arthritides, syphilis?, ulceration, scoliosis, caries, cancer	Recent
1882	Fletcher	Prehistoric man	Trepanation, traumatism	Recent
1885	Graff	Crinoids	Parasitism	Carboniferous
1886	Leidy	Mastodon	Caries	Pleistocene Florida
1895	Virchow	Cave-bear and cave-lion	Arthritides, hypertrophy, caries, fracture, osteomyelitis	Pleistocene Prussia
1896	Virchow	do	do	do
1898	Williston	Mosasaur	Osteoperiostitis	Cretaceous Kansas
1900	Renault	Fishes	Bacteria, fungi, caries	Permian France
1901	Schwalbe	Paleolithic man	Caries, fracture	Pleistocene Neanderthal
1901	Hatcher	Dinosaur	Co-ossification of caudal vertebrae	Comanchean Wyoming
1903	Riggs	Dinosaur	Fracture and callus of rib	Comanchean Wyoming
1904	Parker	Lansing man	Arthritis	Recent Kansas
1905	Orton	Mound Builders	Syphilis and other lesions	Ohio Valley
1907	Eliott-Smith	Egyptians	Numerous diseases	Recent Egypt
1907	Lull	Dinosaur	Fracture, necrosis	Cretaceous Wyoming
1908	Wood-Jones	Egyptians	Numerous diseases	Recent Egypt
1909	Auer	Crocodile	Necrosis with evidence of metastasis	Jurassic England
1909	Gilmore	Dinosaur	Tuberculous necrosis (?)	Comanchean Wyoming
1909	Schlosser	Cave-bear and associated animals	Necrosis, spondylitis deformans and other arthritides	Pleistocene Germany

Date	Author	Animals Afflicted	Diseases	Geological Age Locality
1909	Stromer	Crinoids	Parasitism	Carboniferous
1909	Shattock	Pharaoh of Egypt	Arterio-sclerosis	Recent Egypt
1909	Wieland	Turtle, Dromocyon	Fractures	Cretaceous & Eocene, Kansas & Wyoming
1911	von Huene	Phytosaur	Fracture, necrosis, callus in snout	Triassic Germany
1911	Merriam	Saber-toothed cat	Various	Pleistocene California
1911	Abel	Review of literature on Paleopathology		
1911–13	Hrdlička	Pre-Columbian, Indians of N. A. Incas of S. A.	Various	Recent North and South America
1911–13	Ruffer	Ancient Egyptians	Numerous diseases	Recent Egypt.
1912	Gilmore	Dinosaur	Necrosis	Comanchean
1912	Raymond	Neolithic man	Various	Pleistocene?
1913	Fischer	Paleolithic man	Various	Pleistocene
1915	Troxell	Camel	Hypertrophy	Pleistocene Texas
1915	Gilmore	Dinosaur	Fracture	Comanchean Wyoming
1915	Walcott	Algae	Bacteria	Algonkian Montana
1916	Moodie	Review of literature		
1917	Moodie	Dinosaur	Arthritides	Comanchean Wyoming
1917	Klebs	Chiefly ancient Egyptian (Review of field of work).		
1918	Moodie	Dinosaurs and Mosasaurs	Fractures, necrosis, etc.	Cretaceous
1918	Moodie	Fossil Vertebrates	Opisthotonos	Various
1918	Moodie	Fossil Animals	General Survey of fossil Pathology	Various
1918	Moodie	Ancient man	Various	General
1921	Clarke	Paleozoic invertebrates	Dependence	Paleozoic
1921	Ruffer	Ancient Egyptians	Collected essays	Recent

Cotte (1916) has studied the microscopical anatomy and chemical analysis of mummified tissues from Egypt and North America, but has added nothing new to the knowledge of paleopathology.

A discussion of the studies of the evidences of disease among ancient man will be given in the chapters dealing with these subjects.

NATURE OF ANCIENT DISEASES

The pathological conditions of the early vertebrates do not indicate types of disease which differ essentially from those of today. Fractures in the skeletons of the early reptiles were almost always simple fractures, because the bones of the majority of ancient reptiles were solid. Necroses, arthritides, osteomata, and other hyperplasias do not differ at all from modern lesions of the same type.

The nature of the disease among ancient animals, it is thus seen, is not to be sharply differentiated from the pathological processes which take place in man at the present day. Disease originated perhaps when races of animals began to go toward extinction, but much work needs yet to be done before we can read aright the history of disease in the skeletal remains of animals which lived and died many millions of years ago.

Conceivably disease may be regarded as a factor in natural selection and may have been as potent in raising the vitality of a persisting species as in lowering the vitality of vanishing forms.

PERSISTENCE OF CERTAIN TYPES OF DISEASE

There is a very interesting parallel which can be drawn from the persistence of certain forms of disease and species of animals and plants. Huxley (1869) many years ago called attention to the persistence of certain species and types of animals throughout all geologic time and the writer has in preparation a study of the persistence of anatomical units of structure which shows that nature adopted a few fundamental forms of structure in the beginning of vertebrate life and has simply expanded and modified these units in all subsequent development.

In the history of disease there have likewise been a few forms of disease which have persisted almost unchanged so far as their effects are concerned. Such diseases as caries, alveolar osteitis, various types of necroses all arose early in the history of vertebrate life and have changed but little, if at all, in subsequent time.

The following table shows the time of occurrence of certain pathological processes and such data of later persistence as the meager known records will allow.

		Diseases																					
Epochs	Periods	Arthritis deformans	Malaria	Exostoses	Fractures with callus	Alveolar Osteitis	Opisthotonos	Caries	Anomalies	Necroses	Deforming Arthritides	Parasitism	Dermoid Cysts	Spondylitis Deformans	Osteoperiostitis	Osteosarcoma	Osteoma	Trephining	Osteomalacia	Syphilis	Hemangioma	Tuberculosis	Actinomycosis
Recent	Aztecs, 300-1521 A.D. Nahua Maya, 200 B.C. ? 1517 A.D.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Inca, 1300 B.C.? (900 A.D.)-1532 A.D.	x	..	x	..	x	..	x	..	x	..	..	..	x	x	..	x	x	x	?	..	..	..
	N. A. Indians, 500-1492 A.D.	x	..	x	x	x	..	x	x	x	..	..	..	x	x	..	..	?	..	?	..	..	..
	Egyptians, 6000 B.C.-500 A.D.	x	x	x	x	x	..	x	..	x	x	x	x	x	x	x	..	?	..	?	..	x	..
Holozoic	Neolithic 3000-200 B.C.	..	..	x	x	x	..	?	..	x	x	..	..	x	x	..	..	x	..	?	..	x	..
	Paleolithic 100,000-12,000 B.C.	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Cenozoic	Early Pleistocene 500,000-100,000 B.C.	..	..	x	x	x	..	x	x	x	x	x	..	x	..	..	..	..	..	..	..	..	..
	Pliocene	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..	..	x	x
	Miocene	..	..	x	x	..	x	..	x	x	..	..	..	x	..	..	..	..	..	..	..	..	x
	Oligocene	..	..	x	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Eocene	..	..	..	x	..	..	..	..	..	..	..	..	x	x	..	..	..	x	..	..	..	..
	Cretaceous	..	..	x	x	x	x	x	..	x	x	..	..	x	x	..	x	..	..	..	..	..	..
	Comanchean	..	..	x	x	..	x	..	..	..	x	..	..	x	..	..	..	..	..	..	x	..	..
Mesozoic	Jurassic	..	..	x	..	..	x	..	x	x	..	..	..	..	..	..	..	..	..	..	..	..	..
	Triassic	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Paleozoic	Permian	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Carboniferous	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..
	Devonian	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..
	Silurian	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Ordovician	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Cambrian	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Proterozoic	Algonkian	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Neo-Laurentian	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Archeozoic	Paleo-Laurentian	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

MEASUREMENT OF GEOLOGIC TIME

The methods and results of the measurements of geologic time have recently been reviewed by Barrell (1917). The results will be interesting in connection with the statements made as to the relative ages of different pathological processes. It will thus serve as a basis of all statements of age. Barrell gives the following methods which have been used with varying results:

1. Measurements of time based on erosion.
2. Evidence chiefly from sedimentation.
3. Estimates based on rhythms in sedimentation.
4. Estimates of total time based on oceanic salts.
5. Estimates of time based on loss of primal heat.
6. Measurements of time on the basis of mammalian evolution.
7. Measurements of time based on radioactivity.

The earliest estimate of the magnitude of geologic time, based on the evidence of life transformation in successive periods as seen in the fossilized animals, was made by Sir Charles Lyell (1867) who stated that 20,000,000 years were demanded for a complete change in the species of each period, and since there were in his estimation twelve periods, there would necessarily be demanded 240,000,000 years for the consummation of organic evolution since the opening of the time when organic life became possible. This estimate did not consider, however, the vast stretches of time which preceded the first recognizable beginnings of life. Darwin (1897) thought that 200,000,000 years was not enough for the perfection of organic evolution as he saw it. Huxley (1869), too, regarded the testimony of the rocks as being indicative of an almost indeterminable time which could only be appreciated by breaking it up into periods.

Lord Kelvin first called attention to an apparently erroneous conception on the part of the geologists in that the high internal temperature of the earth, increasing inwards as it does, and from the rate of loss of its heat, fixed a limit to the planet's antiquity. He wished the geologists to be content with some twenty millions of years.

An attempt was then made to determine the length of the Pleistocene to be used as a unit of time for comparative measurements, but the results varied between 25,000 and 1,500,000 years. The latter figure is nearer the one adopted by Penck and Matthew (1914). The latter student states on the basis of his studies of the time ratios in the evolution of mammalian phyla, that the Cenozoic is about one hundred times

as long as the Pleistocene. He regards the Mesozoic as four times as long as the Cenozoic. Adopting 500,000 years for the Pleistocene as a unit, on the basis of Matthew's estimates we would have the following values:

Pleistocene	500,000 Years
Cenozoic	50,000,000 Years
Mesozoic	200,000,000 Years

These estimates gave a higher order of magnitude than had before been obtained, but are strongly supported by Barrell as being of the right order of magnitude. The evidence from radioactivity suggests that 60,000,000 may be granted for the Tertiary (Cenozoic) rather than the 3,000,000 years which has been commonly accepted as the duration of the epoch.

The study of radioactive substances has done much to modify our conceptions of the magnitude of geologic time, as may be seen by referring to the table of geologic time given below (p. 93). The detection in 1896 of the Becquerel rays given out by uranium minerals led up to the epoch-making discovery of radium. This discovery opened the way for the revelation of a whole series of radioactive substances whose activities have had a decided influence on the estimates of the earth's age. Concerning the methods of testing the ages given by radioactivity Barrell remarks:

> In the last third of the nineteenth century physics, in the embodiment of its leaders, Kelvin, Helmholtz, Tait, and others, spoke with assurance on the limits of geologic time. Geologists sought to meet their demands, in so far as they could, but such men as Huxley, Geikie, Goodchild, and others, giving greater weight to the geologic evidence refused to accept the restrictions which were set. We have lived to see unsuspected sources of energy discovered, stupendous in amount, which wholly remove the former limitations on the age of the earth and set new boundaries far beyond what, to most geologists, has seemed the testimony of the evidence.
>
> After the one experience in the fallibility of physical argument notwithstanding its mathematical character, it would certainly be unwise for geologists to accept unreservedly the new and larger measurements given by radioactivity. There may be here, also, factors undetected and unsuspected which vitiate the results. The radioactive measurements, however, can and should be tested by the degree of concordance or discordance of the several results when compared with each other, and also with independent lines of evidence, especially geological.

The "New Table of Geologic Time," in Barrell's paper, shows the varying results attained by the different lines of investigation, outlined above, as well as the adjustment of the evidence as seen in the geologic records.

DESCRIPTIONS OF FIGURES 5-7 AND PLATES VIII–X ILLUSTRATING CHAPTER I

FIGURE 5

Femur of a large adult cave bear, *Ursus spelaeus*, which shows a healed fracture somewhat below the middle of the shaft and exhibits numerous evidences of necrosis. On the posterior surface there are two rather deep canals or sequestrae, shown in figure j, Plate VIII. This specimen is from the Pleistocene of Europe. (After Mayer.)

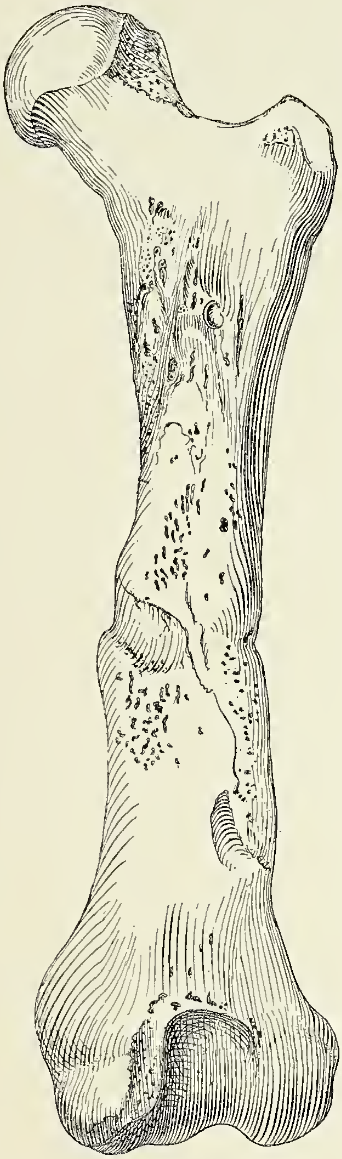


FIGURE 5

FIGURE 6

FIGURE 6

Baron Georges Cuvier. French Comparative Anatomist and Paleontologist, 1769–1832.

Figure 6

FIGURE 7

FIGURE 7

Upper figure.

Rudolf Ludwig Virchow, German Pathologist and Anthropologist, 1821–1902.

Lower left figure.

Phillipp Franz von Walther, 1782–1849. German surgeon who wrote one of the first essays on Paleopathology.

Lower right figure.

Carl Alfred von Zittel, 1839–1904. German paleontologist.

FIGURE 7

PLATE VIII

PLATE VIII

PATHOLOGICAL BONES OF PLEISTOCENE CAVE-BEARS.

a. Left mandibular ramus of a cave-bear, *Ursus spelaeus*, Pleistocene of Europe, showing the ravages of disease. Caries and the absorption of alveolar processes, as well as necrotic sinuses, are evident in the bone. The specimen indicates a very old individual.

b. Radius showing carious hyperplasia of the shaft recalling some of the osseous lesions seen in syphilis.

c. Portion of a fractured rib which had evidently healed imperfectly with the formation of considerable callus and necrotic sinuses.

d. Phalange showing hypertrophy.

e. Section through same showing increased thickness of bone and decrease of the medullary space.

f. Metacarpal showing lesions of arthritis.

g. Phalange of cave-bear showing arthritic lesions. Dorsal view.

h. Cervical vertebra showing lesions.

i. Sacral vertebra showing a diseased condition of right transverse process.

j. Necrotic sinuses in fractured femur of cave-bear (shown in Figure 5).

k. Two lumbar vertebrae ankylosed by lesions of spondylitis deformans.

(a, j and k after Mayer; b, c, d, e, and i after Virchow; f, g and h after Schlosser.)

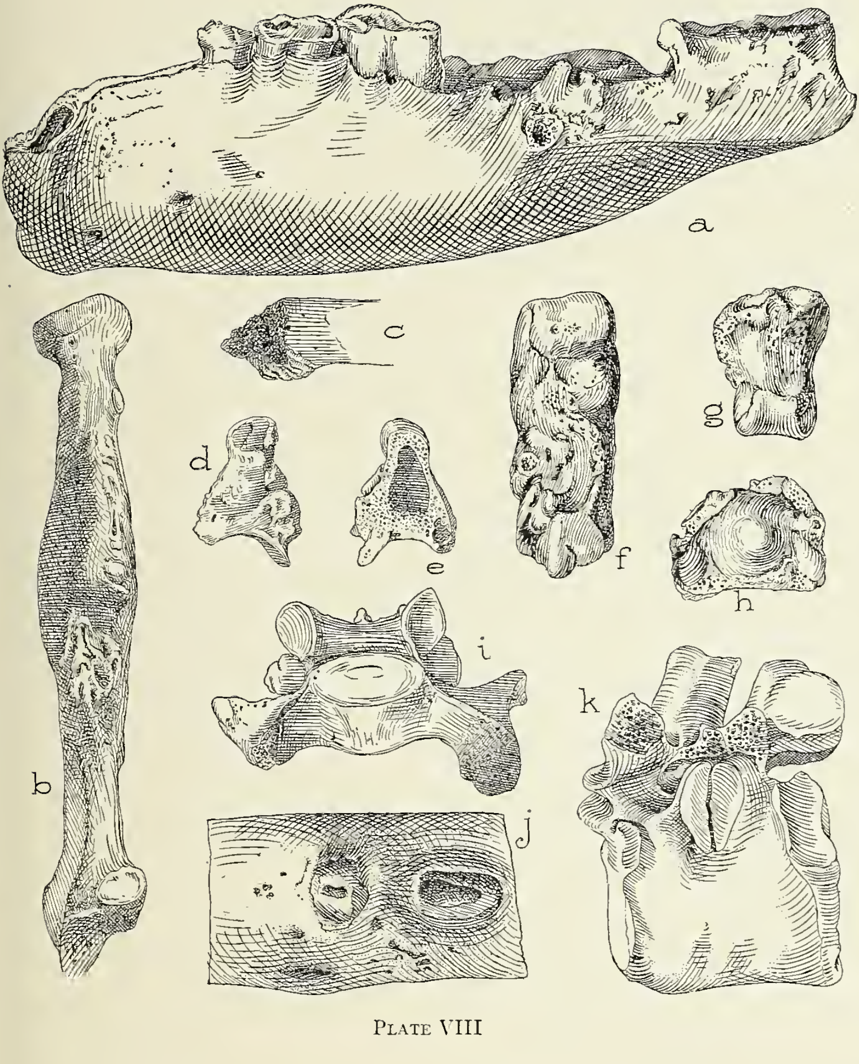


PLATE VIII

PLATE IX

PLATE IX

TRAUMATISMS AMONG FOSSIL REPTILES

a. Broken right horn core, attesting a fight or accident in an ancient reptile, *Triceratops*, a three-horned dinosaur from the Cretaceous, 16,000,000 years ago. Specimen preserved in the U. S. National Museum. Courtesy of Mr. Charles Gilmore. (Described in: Proc. U. S. Natl. Mus., lv. 97–112, pl. 9, 1919.)

b. Pathological camel phalanx described by Troxell from the Pleistocene of Texas. Original in Yale University Museum. Courtesy of Dr. R. S. Lull.

c. Amputated right tibia and fibula of a giant sea turtle, *Archelon ischyros*, from the Pierre Cretaceous of the South Fork, Cheyenne River, South Dakota, 35 miles S. E. of the Black Hills. This was doubtless bitten off while the animal was young by either a giant fish or a carnivorous reptile since the bones are considerably smaller than those on the left side, indicating atrophy. Skeleton mounted in Yale University Museum. This is the largest fossil turtle known, having a length of over twelve feet and an estimated weight of three tons. Photograph by courtesy of Dr. R. S. Lull.

PLATE IX

PLATE X

PLATE X

PATHOLOGIC LESIONS ON MESOZOIC REPTILES

a. Lesions of spondylitis deformans uniting two caudal vertebrae of a giant dinosaur, *Diplodocus*, from the Comanchean of Wyoming. The lesions have involved all the periphery of the articular surfaces of the two vertebrae. Specimen in Carnegie Museum at Pittsburgh. (After Hatcher.)

b. Pachyostosis or hyperostosis (Giantism) in a sacral vertebra and ribs of an early Triassic nothosaur. (After Volz.)

c. Pathological femur of a Jurassic crocodile, *Metriorhynchus moreli*, from the Oxford Clay of England.

d. Diseased sacral vertebra of same animal (After Auer).

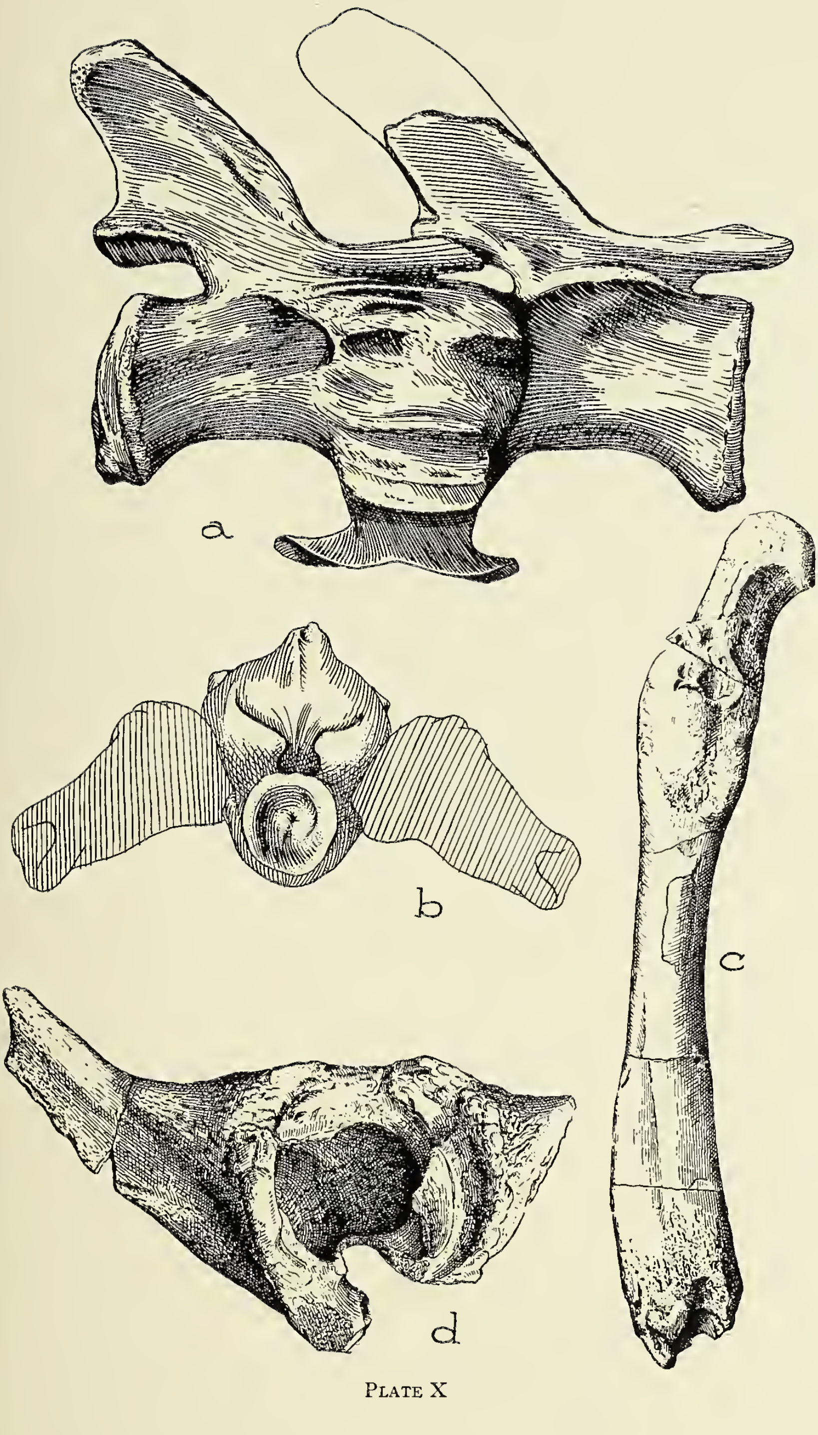


Plate X

CHAPTER II

THE ORIGIN OF DISEASE

Speculations as to the antiquity of disease. Geological beginnings of disease. Tabulation of all geological evidences of disease. Lesions of parasitism among Paleozoic animals. Pathology of the early fishes, amphibians and reptiles.

SPECULATIONS AS TO THE ANTIQUITY OF DISEASE

Speculations usually precede discovery. Suggestions and theories precede definite concepts. The first recorded suggestion that there might be considerable antiquity to disease and pathological processes was made by von Walther in 1825 when he stated:

> We have no historical data to prove how old disease is nor when it first attacked the poor, sinful, human race.

Had von Walther only realized it he had in his possession sufficient evidence to prove a portion of the antiquity of disease, since the bones he studied were of Pleistocene age, representing mammals tens of thousands of years old. Possibly in his opinion disease was not disease unless it afflicted the human race. We now know that disease is the same whether manifested in man or in the lower animals.

The possible presence of disease among animals of remote epochs of the earth's history was first suggested by Metchnikoff (1905). He, too, was the first to point out the identity of many forms of disease which are common to man and the animals. He says:

> Diseases in general and infective diseases in particular were developed on the earth at a very remote epoch.

Mayer (1854) was doubtless the first student to realize the significance of Paleopathology, although many had previously studied diseased fossil bones. He grasped clearly the significance of his studies on fossil bones to the history of medicine in its broader aspects. Schmerling (1835), too, had some grasp of the situation and contributed one of the earliest memoirs to Paleopathology. His results were of great importance.

The possibility of finding evidences of disease in a fossil condition appealed strongly to George Fleming[1] who says:

> True, the fossil remains of creatures exposed now and then in the upper crust of the earth make us acquainted to a certain extent, with diseases to which the

[1] Animal Plagues, their History, Nature and Prevention, 1871, p. 1.

lower orders of creatures were subject, "long ere the water overflowed and the mountains sank," but their feeble testimony serves us but little.

At the time he wrote little was known of paleopathology and the nature of fossil diseases, and that little was largely based on lesions studied on the remains of Pleistocene mammals.

It was Sir Marc Armand Ruffer (1914) who really consummated the union of ancient and modern evidences into a single science which he called "Paleopathology." Unknown to him the word had previously been used in a slightly different conception, dealing with the most ancient aspects of the subject. His ideas of the most remote phases of paleopathology were therefore somewhat speculative. It is only within recent years that a general conception of this subject has been reached.

GEOLOGICAL BEGINNINGS OF DISEASE

The introduction of disease among the early animals was doubtless a gradual process and the very oldest evidences were so indefinite as to be unrecognizable. The intimate association of animals during the early part of the Paleozoic resulted in conditions of symbiosis and a mild form of parasitism which are the first phases of disease found in the history of animal life on earth. Clarke (1908), who has studied the beginnings of dependent life more closely than any other paleontologist is of the opinion that there are definite evidences of true parasitic conditions in the Paleozoic faunas as early as the Devonian. There are no known cases or examples of infection, no tumors, few traumatic lesions or injuries of any kind prior to the Devonian. An interesting case of parasitism from the Mississippian of Indiana, showing on the tegmen of the crinoid successive growth marks made by an attached snail, represents the benign form parasitism assumed early in the Paleozoic; a condition lasting until near the close of that epoch.

The oldest examples of pseudo-parasitism known in Paleozoic animals seldom resulted in the formation of excessive pathological growth, but were usually benign in their results. The very beginnings of disease we may never see and we are not safe in saying that disease began at a time when we find the first obvious lesions. A period of time enormous in its extent elapsed before pathology had progressed sufficiently to produce visible results in the hard parts of early animals.

TABULATION OF ALL GEOLOGICAL EVIDENCES

The relation of the early races of animals to disease may be well shown in the following comprehensive table of evidences showing in

detail the pathological results known to occur in the individual geological periods. The table is a simple statement of results so far obtained, and on the basis of these results the graph (Figure 2) showing the increase of disease was based. Additions to the table in years to come may completely change our present conceptions of the origin and development of pathology but at the present time the information expressed in the table is all we possess. The evidences from the Paleozoic are scanty because there has been little search for them and it will be interesting to see what the results will be when it is possible to tabulate all evidences of pathology among the invertebrates of the early periods of the earth's history.

TABULATION OF ALL GEOLOGICAL EVIDENCES OF DISEASE

Eras	Geological Periods	Evidences of Disease	Animal and Plant Life
Psychozoic	Recent 3,000 ft. 25,000 yrs.* (200,000 yrs.)	Diseases of the ancient Egyptians; the pre-Columbian Indians of North America; the Incas of South America and Neolithic Man of Europe. Lesions on Extinct Mammals.	Rise of world civilization. Age of Man. Domesticated Animals.
	Pleistocene 4,500 ft. 525,000 yrs. (800,000 yrs.)	Spondylitis deformans on cave bears; fracture and callus; necroses; caries in mastodon; osteomyelitis; exostoses on femur of Pithecanthropus.	Paleolithic Man in Europe; world-wide extinction of great mammals; period of extensive glaciation; transformation of man-ape to man.
	Pliocene 5,000 ft. 500,000 yrs. (1,000,000 yrs.)	Actinomycosis, spondylitis deformans.	Ancient types of horses; many groups of extinct mammals.
Cenozoic**	Miocene 9,000 ft. 900,000 yrs. (12,000,000 yrs.)	Fracture and callus; hypertrophy; actinomycosis; dental caries; pyorrhea; necrosis	Culmination of mammals.
	Oligocene 12,000 ft. 1,300,000 yrs. (16,000,000 yrs.)	Fracture and callus.	Rise of higher mammals.

Eras	Geological Periods	Evidences of Disease	Animal and Plant Life
	Eocene 12,000 ft. 1,400,000 yrs. (20,000,000 yrs.)	Dental fistula; necrosis; osteomalacia; Spondylitis deformans	Introduction of higher mammals; vanishing of archaic mammals; introduction of grasses.
	Epi-Mesozoic interval of uncertain length.		Rise of archaic mammals.
	Cretaceous 18,000 ft. 3,600,000 yrs. (40,000,000 yrs.)	Osteoma; exostoses; fracture and callus; dental caries; necrosis; hypertrophy; arthritides; alveolar osteitis; pachyostosis; osteoperiostitis; opisthotonos;	Extinction of great reptiles; extreme specialization of reptiles; small mammals; toothed birds; large bony fishes; deciduous trees.
	Comanchean 9,800 ft. 2,500,000 yrs. (25,000,000 yrs.)	Haemangioma; arthritides; necrosis; opisthotonos; fracture with callus; parasitism.	Giant reptiles; rise of flowering plants; small mammals.
Mesozoic	Jurassic 8,500 ft. 3,000,000 yrs. (35,000,000 yrs.)	Opisthotonos; pleurothotonos; suppurative necrosis in crocodile; indication of metastasis.	Rise of birds; flying reptiles; small mammals; first turtles; ganoid fishes.
	Triassic 12,000 ft. 3,350,000 yrs. (35,000,000 yrs.)	Opisthotonos; pleurothotonos; fracture and callus; necrosis.	Rise of dinosaurs; archaic reptiles; labyrinthodonts; fishes.
	Epi-Paleozoic interval of uncertain length.		Extinction of ancient life.
	Permian*** 14,000 ft. 3,500,000 yrs. (25,000,000 yrs.)	Oldest known callus and fracture; caries in fish bone; bacteria.	Modern insects; archaic reptiles; armored amphibians; scaled fishes; periodic glaciation.

Eras	Geological Periods	Evidences of Disease	Animal and Plant Life
Paleozoic	Pennsylvanian 16,000 ft. 3,800,000 yrs. (35,000,000 yrs.)	Myzostomid parasite in crinoid stem; fungi; bacteria.	First reptiles; numerous amphibians, first bony fishes; insects; rise of land floras.
	Mississippian 9,500 ft. 2,900,000 yrs. (50,000,000 yrs.)	Hypertrophy and asymmetry in brachiopods. Depauperization of fauna.	Amphibian footprints; rise of ancient sharks.
	Devonian 22,000 ft. 4,600,000 yrs. (50,000,000 yrs.)	Beginnings of parasitism.	First footprints of land vertebrates; first land floras; dominance of armored fishes; insects; lung fishes.
	Silurian 15,000 ft. 4,200,000 yrs. (40,000,000 yrs.)	Hypertrophy in crinoid stem. Hypertrophy in a snail.	First air-breathers (scorpions); lung fishes; fresh water fishes; starfishes; giant arachnids.
	Ordovician 17,000 ft. 4,800,000 yrs. (90,000,000 yrs.)	Traumatism	First armored fishes; corals; nautilids; dominance of trilobites; 5,000 species of invertebrates known; rise of shelled animals.
	Cambrian 18,000 ft. 5,300,000 yrs. (70,000,000 yrs.)	Communism; beginnings of dependent life.	1000 species of invertebrates; first known marine faunas; brachiopods; trilobites; corals; sponges; protozoa; molluscs; algae; no land plants.
	Epi-Proterozoic Interval of great duration.		

Eras	Geological Periods	Evidences of Disease	Animal and Plant Life
	Algonkian 24,000 ft. 13,000,000 yrs.		Age of primitive marine invertebrates; oldest known fossils; worms; radiolaria; Bacteria (non-pathogenic)?
Proterozoic (=)	Neo-Laurentian 50,000 ft. 20,000,000 yrs.		No fossils known.
Archeozoic (♯)	Paleo-Laurentian 98,000 ft. 46,000,000 yrs.		No definite evidences of life; limestone deposits may be some indication of biological conditions. This period witnessed the origin of life and the beginning of the world.

* The estimates here given of the duration of the geological periods are conservative and suffice to show the great antiquity of disease. In parenthesis is given the estimate based on radioactive substances.

** Matthew estimates 10,000,000 years as the duration of the Cenozoic, basing his estimate on the evolution of the mammals. Studies of radioactive substances indicate a duration of 55,000,000 years.

*** The Permian, Pennsylvanian and Mississippian are often grouped together as the Carboniferous.

= The duration of the Proterozoic was as great as all post-Cambrian times, which have been estimated as high as 415,000,000 years.

♯ The study of radioactive substances gives estimates as high as 1,600,000,000 years for the duration of the Archeozoic.

LESIONS OF PARASITISM AMONG PALEOZOIC ANIMALS

The oldest evidences of disease are those of parasitism. These are often indefinite lesions of the hinge-line of molluscs, scars under the mantle, enlargements of various parts, or markings of the parasite upon the host. Often, especially in the late Paleozoic, the lesions take the form of tumors in crinoid stems, due apparently to the presence of a myzostomid. Such lesions are described in Chapter VIII. There must have been a period of mild parasitism preceding these which caused

lesions on the hard parts, for it often requires a considerable duration of infection to produce such a lesion. Thus we are aware that the earliest known lesions of parasitism (Plate XI) do not represent the beginnings of that pathological state which is concerned with the beginnings of disease.

PATHOLOGY OF THE EARLY FISHES, AMPHIBIANS AND REPTILES

The remains of the early vertebrates, prior to the Permian, have shown no noteworthy pathological lesions. There may have been diseases among these early forms but the lesions have not yet been described, as may be seen by referring to the Table of Geological Evidences. We find, to be sure, certain laterally compressed fishes preserved in the attitudes of opisthotonos and pleurothotonos in horizons prior to the Permian. These attitudes may have been due to spastic distress induced by cerebrospinal infections or to some form of poisoning. This possibility must be considered in speaking of early states of disease. Ingress of infecting bacteria was relatively easy through the unprotected brain case of the early vertebrates. The presence of infecting bacteria has been established through the researches of Renault and is fully outlined in Chapter IX.

Several pathological conditions are indicated among the Permian reptiles, but of the pathology of the Paleozoic Amphibia nothing whatever is known. Remains of these animals are not uncommon in certain formations and there is a large literature but no mention of pathology occurs in the discussions of these ancient animals. Among the hundreds of Coal Measures Amphibia examined for the preparation of my monographic revision of the North American forms, not a single one showed any evidence of pathology. I do not understand from this that disease did not exist among the Paleozoic Amphibia. It rather means that we have not yet seen the lesions of disease among these forms.

CHAPTER III

PATHOLOGICAL CONDITIONS AMONG FOSSIL PLANTS

By Edward W. Berry, Johns Hopkins University

Introduction. Extinction. Parasitism. Callus and injury. Fossil fungi. Bacterial activity. Spot fungi. Activities of insects. Teratology. Descriptions of Plates XI-XIII illustrating Chapters II and III.

INTRODUCTION

Plant pathology, which is so important a branch of botanical science, includes in its subject matter not only symptoms and causes of the maladies which threaten the lives of plants, but those that result in abnormalities of structure, form or appearance which are either directly injurious or even merely unsightly, as well as the remedies and treatments for combating them.

It is obvious that the study of fossil plants has no immediately practical results to offer to the economic botanist, and it is equally obvious that the student interested in the phytopathology of former geologic times is limited to those few causes and results that are capable of preservation in the fossil record. The present brief sketch must therefore be regarded as merely an enumeration of some of the more obvious records that may be considered as coming under the head of wounds and parasitism irrespective of whether or not they may be included under the subject of pathology in a strict sense.

EXTINCTION

One of the outstanding problems of the paleontologist whether he deal with animals or plants is the specific factors that have led to the extinction of the myriads of organisms that have flourished in past ages. General climatic or other environmental changes have no doubt been influential, but these were imperceptibly gradual, and it is doubtful if they have ever been primary factors. If this were the case why is it that the trilobites rapidly reached their climacteric development and disappeared during the Paleozoic, while their contemporaries—the very similarly organized true crustacea, are abundant at the present time. What were the factors which led to the extinction of the various

races of seed ferns, lepidophytes and arthrophytes of the Paleozoic or of the abundant cycadophytes of the Mesozoic? They were cosmopolitan types and plastic enough to adapt themselves to the varying environments throughout the world in those days. To be sure many types became extinct by evolutionary modification into something else, but others appear to have vanished abruptly like the sphenophyllums of the Paleozoic or the cycadeoids of the Mesozoic and to have left none but collateral descendants. Undoubtedly competition was a great factor and probably micro-organisms played a considerable part, and yet if it is legitimate to judge from their not very closely related modern representatives, all of these extinct plant groups which I have mentioned were singularly free from insect and fungus pests as compared with the more modern flowering plants. The causes of the extinction of individual species is even more difficult to visualize than that of plant groups. I recall no modern pest that succeeds in the extermination of its host, whether it be chestnut blight, cotton boll insect or potato beetle. And even such a catastrophe as overwhelmed the tile fish a score of years ago did not result in extermination, nor did events in the past of far greater magnitude, such as the lava flows of the Deccan or those of the Columbia River region, have more than a local influence on the floras of those regions. It is conceivable, even very probable, that single specific causes were never efficient except as single factors in a chain or complex of more or less unfavorable conditions due to changes in physical environments such as temperature, water supply, humidity, etc., and to changing organic environments such as increased competition of more competent forms or unusual increase of parasitic forms, both animal and vegetable.

The study of pathological conditions in fossil plants may be said to be in its embryonic stage of development. It is true that some few by-products of anatomical and morphological studies of fossil plants afford isolated instances of pathological conditions, but these are limited and their discovery is largely accidental, depending on the chance location of a rock section, nor does it seem possible ever to go beyond such facts as are furnished by evidences of traumatism caused by wounds or by insect or fungal activities.

The pathological effects of such factors as too great or too little moisture, too much or too little light, or too great or too small temperatures—such things as etiolation or chlorosis, are probably beyond the reach of paleobotanical investigation. Bacteriosis may possibly be inferred from the actual presence of bacteria or undoubted evidence

of their toxic effects, and flux or gummosis may possibly be indicated by the presence of resins or amber pellets, but this is not necessarily true.

PARASITISM

Parasitism itself is not necessarily pathologic in the sense that it is baneful to the host, although it may be assumed that it is invariably a stimulus to abnormal metabolism and generally to abnormal tissue formation, even when we are ignorant of its visible effects. Certain forms of parasitism may be actually beneficial to the host as in the case of the nitrogen fixing mycorrhizae of roots, or those of the roots of sour soil plants such as the blueberry, arbutus, etc., thus becoming symbiotic, the most striking instance of which is furnished by the symbiotic association of algae and fungi to form the lichens.

In dealing with fossil plants it is frequently impossible to determine whether the observed parasitism is pathologic in the strict sense, nor is it usually possible to determine whether the bacteria, fungi, or other organisms that may be observed, invaded the tissues before the death of the individual or subsequently.

CALLUS AND INJURY

Cicatrization of injured tissue, or callus formation, is a form of pathologic activity that is most frequently observed in fossil plants. It was commented upon in print by Goeppert[1] as early as 1882. Numerous specific cases have come to light. For example Seward[2] in 1898 described callus wood in a calamite from the English Carboniferous and Stopes[3] has described a second English Carboniferous calamite in which the wound was so deep that it had penetrated the vascular cylinder, the injured and partially decayed primary strands being shut off and the wound closed by callus, which had formed inrolled and inverted wood in the pith cavity. Holden[4] described similar callus wood in a superficially wounded Myeloxylon (petiole) from the Carboniferous, which showed clearly the meristematic cortical tissue, wound cambium and cork cells (periderm); and Jeffrey has recently described similar features in more modern material from this

[1] Goeppert, H. R., Beiträge zur Pathologie und Morphologie fossiler Stämme. Palaeont. Bd. 28. 12 pp. 5 pls. 1881.

[2] Seward, A. C., Fossil Plants, vol. 1, pp. 319–320, t.f. 80, 1898.

[3] Stopes, M. C., A Note on Wounded Calamites. Ann. Bot., vol. 21, pp. 277–280, pl. 23, 1907.

[4] Holden, H. S., Note on a Wounded Myeloxylon. New Phyt. vol. 9, pp. 253–257, t.f. 17, 18, 1910.

country. The last author has made the abnormalities due to the stimulus of wounding, which commonly appear on the opposite side of the stem from the actual wound, and comprise the formation of traumatic resin canals in non-resiniferous forms, the formation of ray tracheids in forms in which they are normally absent, changes in tracheid pitting, etc., the basis for considerable phylogenetic speculation.[5]

Where wounds are not successfully healed the continued stimulus often results in a cancer-like growth of progressively increasing size known as a "burl," "burr," or "knaur." Such doubtless occur at many geologic horizons. They are frequent on Pleistocene specimens of Taxodium, and Goeppert (op. cit.) has described some from earlier, and in some cases, Paleozoic horizons.

The most striking example of cicatrization known in the geologic record is furnished by the self pruning (Cladoptosis) of the Carboniferous lepidophytes commonly referred to the form-genus Ulodendron. These are only known as impressions and show large elliptical cup shaped scars in vertical series on Bothrodendron and other lepidophyte stems. They have been known since 1818 and students have exercised their ingenuity in explaining these Ulodendron scars which are frequently several centimeters in diameter in a variety of ways. They have been considered as scars left by the pressure of the bases of sessile cones, as scars of adventitious roots, fruiting branches, etc. Watson[6] in 1908 furnished presumptive proof that these Ulodendron scars were due to self pruning of often large branches, and this has been confirmed by the more recent researches of Renier.[7]

Probably the chief agents of pathological effects in the past as at the present time were bacteria and fungi. As previously remarked the student interested in the pathology of plants during former geologic times has usually no means of determining whether the traces of fungi found fossil were pathogenic or were merely performing the normal function of decay and dissolution in the reduction of complex dead matter to simple compounds available for plant food. I will, therefore, mention a few examples of fossil forms and will largely disregard the distinction between pathologic and non-pathologic types. (Plate XII.)

[5] See for example Jeffrey, E. C., Wound Reactions of Brachyphyllum. Ann. Bot., vol. 20, pp. 383–394, pls. 27, 28, 1906, and numerous subsequent papers.

[6] Watson, D. M. S., Mem. Proc. Manchester Lit. Phil. Soc. vol. 52, 14 pp. 2 pls. 1 t.f., 1908.

[7] Renier, A., Mém. Soc. géol. Belg. 2, pp. 35–82, pls. 7–9, 1910.

FOSSIL FUNGI

The small size and delicate nature of most fungi render their successful preservation as fossils more or less exceptional and their discovery is also fortuitous in connection with histological work upon more or less fragmentary plant tissues that have become petrified. Despite these facts anyone who has interested himself in histologic investigation of fossil plants becomes convinced that both parasitic and saprophytic forms were probably as abundant as far back as representative remains of terrestrial floras have been found, certainly as early as Carboniferous times, while direct evidence of bacteria extend back to pre-Cambrian times. (Plate XIII.)

The hard and leathery sporophores of forms like the modern bracket fungi might be expected to be preserved as fossils, and a few undoubted instances of Tertiary and Pleistocene occurrences are indisputable, but such records from older formations are highly untrustworthy, although such negative evidence can by no means be considered as proving their absence during earlier times. One feature that has frequently been commented upon is the fresh and clear cut cortical patterns of the Paleozoic lepidodendrons, sigillarias and their allies, seemingly proving that epiphytes and fungi such as drape the tree trunks in existing humid regions comparable with the coal swamp environments, did not exist in Carboniferous times.

BACTERIAL ACTIVITY

The disorganization of cell walls by the dissolving of the middle lamellae or cement layer by bacterial activity has frequently been observed in fossil woods of all geological horizons from the Lower Carboniferous to the present. Van Tieghem[8] in 1877 was the first to describe these features and to compare them with the results of butyric fermentation caused by the existing *Bacillus amylobacter*. Renault and Bertrand subsequently described a very large number of bacterial occurrences, particularly from Devonian, Carboniferous, Permian and Jurassic rocks, and more recently Walcott[9] has demonstrated the presence of bacteria in the very much older Algonkian rocks, thus lending support to the theory that a pre-chlorophyllic, chemosynthetic stage of plant evolution preceded the chlorophyllic, photosynthetic stage with which we are so familiar as exhibited by the majority of existing plants.

[8] Van Tieghem, P., Bull. Soc. Bot. France, tome 24, p. 128, 1877.
[9] Walcott, C. D. Smith. Misc. Coll. vol. 64, no. 2, 1914.

Among the true fungi fossil occurrences are based upon two classes of remains, namely, such as are preserved in petrified tissues of higher plants, and those forms, both endo- and epiphyllous, as cause pustules or discolored patches on foliage, or form recognizable perithecia on leaf surfaces. Spot fungi have been observed upon fossil foliage preserved as impressions from the Devonian to the present, but their indefinite character usually renders their accurate identification hopeless. It is usually impossible to distinguish between glands, lenticels, insect punctures or fungal ravages, and with the last it is generally impossible to differentiate between pustules due to endophytic forms and actual outgrowths of mycelia with the formation of stromata.

SPOT FUNGI

Vast numbers of fossil spot fungi are recorded in the literature of paleobotany. A majority of these are unsatisfactory in that they fail to afford definite botanical characters, so that only a few examples will be given. Meschinelli[10] prepared a bibliography and check list of fossil fungi for Saccardo's great work on fungi and the reader is referred to this for a rather complete enumeration of fossil forms up to the year 1900.

What probably represent perithecia of *Hysterites cordaitis* Grand' Eury are shown on Cordaites leaves figured by White[11] from the Carboniferous of Missouri, and very many pages could be filled with citations of other records of very similar remains from all geological horizons. A Diospyros leaf infested with a spot fungus and coming from the lower Eocene of Tennessee is shown in the accompanying illustration (Plate XIII, a). Attention might also be called to the very characteristic form on the leaves of Tertiary fan palms from Florida described by the writer as *Pestalozzites sabalana*,[12] and to the petiolar and ray fungi on Eocene palms described as species of Caenomyces.[13]

A considerable number of fungi have also been described from the lower Oligocene amber of the Baltic region.

Turning now to petrified remains a few instances may be noted. A Carboniferous endophytic fungus, probably referable to the Phycomycetes, and named *Perenosporites antiquarius* was described by Worthing-

[10] Meschinelli, A., Fungorum Fossilium omnium Iconographia, 144 pp., 31 pls., 1902.

[11] White, D., Mon. U. S. Geol. Surv. vol. 37, p. 14, pl. 3, 1899.

[12] Berry, E. W., U. S. Geol. Surv. Prof. Paper 98E, p. 46, pl. 8, fig. 3; pl. 9, fig. 9, 1916.

[13] Berry, E. W., Idem. 91, p. 162, pl. 9, figs. 2, 3, 1916.

ton Smith in 1877,[14] and although his illustrations are somewhat idealized similar remains have been described in Carboniferous Lepidodendron material by Cash & Hick,[15] Williamson,[16] and other authors. A form very similar to the English species was described from the French coal measures as Palaeomyces by Renault,[17] and Coulter and Land[18] have recently figured what appear to be antheridia and oögonia which they found in rootlets that had penetrated a Lepidostrobus cone from the Carboniferous of Warren County, Iowa. Jeffrey[19] has described and figured a fungus found in the early Tertiary lignites of Brandon, Vermont, which he calls *Sclerotitites brandonianus* and which he interprets as a sclerotium stage.

From petrified palm wood from the Oligocene of our southern states I have described[20] material in a remarkable state of preservation showing both antheridia and oögonia (*Peronosporoides palmi*), and various other forms showing both mycelia and conidia and referred to Cladosporites. Remains similar to the last mentioned have also been described by Felix,[21] Whitford,[22] and others. Spinose bodies called Zygosporites and comparable with the sporangia of modern forms like Mucor are common in Carboniferous petrified tissues and Renault[23] has described forms from the Permian which he called *Teleutospora milloti* (Puccineae) and others which he named *Mucor combrensis*[24] and Oochytrium. Oliver has described[25] conceptacles containing spores in a petrified leaf of Alethopteris, and similar bodies in the nucellus of the seeds of Sphaerospermum, both from the Paleozoic. A Permian Ascomycete (Rosellinites), unfortunately not petrified, was described by Potonié[26] and Engelhardt has described similar material which he

[14] Worthington Smith, Gardiners Chronicle, vol. 8, p. 499, 1877.

[15] Cash and Hick, On fossil fungi from the Lower Coal Measures of Halifax. Proc. Work. Geol. Polyt. Soc., vol. 7, p. 115, 1878.

[16] Williamson, W. C., Phil. Trans. Roy. Soc. Lond., vol. 172, p. 300, pl. 48, figs. 36–38; pl. 54, figs. 28–33, 1881.

[17] Renault, B., Bassin houiller et permien d'Autun et d'Epinac, fasc. 4, 2e partie, pp. 439, 441, figs. 88–90, 1896.

[18] Coulter and Land, Bot. Gaz., vol. 51, p. 452, figs. 21–23, 1911.

[19] Jeffrey, E. C., Geol. Surv. Vermont, Report 1905–1906, p. 200.

[20] Berry, E. W. Mycologia, vol. 9, pp. 73–78, pls. 180–182, 1916.

[21] Felix, J., Zeits. deutsch, geol. Gesell., 1894, pp. 269–280, pl. 19.

[22] Whitford, A. C., Univ. Studies, Nebraska, vol. 14, 3 pp. 2 pls. 1914.

[23] Renault, B., op. cit. Autun Flora, p. 427, fig. 80d, 1896.

[24] Idem. figs. 80a-80c.

[25] Oliver, F. W., New Phyt., vol. 2, p. 49, 1903.

[26] Potonié, H., Jahrb. k.k. Preuss. geol. Landes. Bd. 9, p. 27, pl. 1, fig. 8, 1893.

referred to the genus Rosellinia from the Oligocene brown coal of Central Europe.[27]

Weiss, some years ago, described the interesting remains of parasitic fungi with the complementary development of wound tissue in Stigmarian rootlets from the lower coal measures of England.[28] Magnus compared this fossil type with the existing Urophlyctis which it resembled in as much of its structure as was discernible as well as in its habit of infesting plants of marshy or wet situations. Weiss accords in this comparison to the extent of naming the fossil form *Urophlyctites stigmariae*. This same author notes a Mycorhiza from the same geological horizon[29] in rootlets of some leidophyte (Rhizonium). The hyphae are for the most part intracellular, but in no case is there any sign of injury to the host. This form, suggesting an early development of symbiosis and nitrogen fixation, was named Mycorhizonium.

The ravages of a Polyporus-like fungus in wood preserved in the Baltic amber beds (lower Oligocene) was described by Conwentz and there can be no doubt but that if an experienced mycologist would study the fossil records, fungi would be found to be present in surprizing numbers. Petrified woods, of all ages, as seen in chance sections, commonly shows mycelial hyphae, both septate with clamp connections and non-septate. These are often seen puncturing the tracheid walls or ramifying over the walls of the vessels and through the bordered pits. The tissues are frequently dissociated through bacterial activities, punctures and striations of the cell walls are observable and testify to fungal activities even when the actual causative agents have failed to be petrified.

ACTIVITIES OF INSECTS

Turning now to possible pathologic conditions caused by the activities of animal organisms it may be noted that the insect stock is an ancient one and that insect activities in past times are observable not only in fossil woods, but in tunnels of leaf miners in fossil leaves, of which many examples have been described in material from the Cretaceous and Tertiary rocks. One finds in the Cretaceous occasional leaves of the flowering plants, preserved as impressions, in which they show every appearance of having been riddled or partially destroyed

[27] Engelhardt, H., Gesell, Isis in Dresden, ab. 4, p. 33, 1887.

[28] Weiss, F. E., A Probable Parasite of Stigmarian Rootlets. New. Phyt., vol. 3, pp. 63–68, fig. 66, 67, 1904.

[29] Weiss, F. E., A Mycorhiza from the Lower Coal-Measures. Ann. Bot. vol. 18, pp. 255–265, pl. 18, 19, 1904.

by caterpillars, and the work of leaf cutting bees has been observed in both Upper Cretaceous and Tertiary leaves.[30] Hypertrophy due to insect punctures or egg laying in plant tissues and resulting in galls, while comparatively rare, is not unknown in the fossil state, particularly in the later geological formations.

For example, a great variety of galls have been collected from the impure peats of the Pleistocene, both in this country and Europe. Moniliform Taxodium leaves resulting from the activity of gall gnats (Cecidomyiids) are very common in the Pleistocene of Maryland. Plate XII, a shows a characteristic gall from the Upper Cretaceous Dakota sandstone.[31] Plate XIII, c shows a petiolar gall from the lower Eocene, of a kind such as are caused by some species of Hemiptera and more commonly by gall flies.[32] Plate XIII, b shows well marked "seed," "tube" or "cone galls" such as are produced by species of Cecidomyia (Diptera) in this case on a leaf impression from the lower Eocene.[33]

Both mines and egg masses of some microlepidopterous insect have recently been described from the Upper Cretaceous of Wyoming[34] and a thorough search through paleobotanical literature or museum collections would undoubtedly result in an indefinite extension of similar instances of insect activity.

The work of eel worms (Nematodes) upon leaves has been described by Frič in Upper Cretaceous leaves from Bohemia.[35]

TERATOLOGY

Abnormal or teratological fossil leaves showing malformation in outline or in the development of puckers are sometimes preserved as fossils but an enumeration of instances would not serve any useful purpose in the present connection.

Williamson in 1880 called attention to Carboniferous wood with traces of borings made by some xylophagus arthropod and to minute coprolites or excreta such as are frequently found within the framework of cells, as well as to oval membrane bounded bodies preserved in

[30] Frič, A., Archiv. Naturw. Landes. Böhm. Bd. 11, p. 167, fig. 9, 1901.

[31] Lesquereux, L. Mon. U. S. Geol. Surv., vol. 17, p. 58, pl. 7, fig. 2, 1892.

[32] Berry, E. W., U. S. Geol. Surv. Prof. Paper 91, p. 33, pl. 56, fig. 2, 1916.

[33] Idem., p. 33, pl. 111, fig. 1.

[34] Knowlton, F. H., U. S. Geol. Surv. Prof. Paper 108 F, pp. 87, 93, pl. 33, fig. 5; pl. 36, fig. 5, 1917.

[35] Frič, A., Archiv. Naturw. Landes. Böhm., Bd. 11, pp. 166, 167, 177, figs. 6, 8, 27, 1901.

a petrified state that apparently represent the eggs of some insect.[36] Insect galleries in fossil woods have also been noted by numerous other students, e.g., Geinitz in 1842 called attention to their presence in Upper Cretaceous woods from Saxony[37] and in 1855 he described similar traces in the stems of Sigillaria from the Saxon Carboniferous, which he doubtfully attributed to the work of Coleoptera.[38] Desmarest noted[39] similar galleries in French specimens as early as 1845 and Charles Brongniart, the celebrated student of fossil insects, described both Carboniferous[40] and Lower Cretaceous[41] insect galleries in petrified woods, even naming the insects that caused them as Hylesinus and Bostrychus respectively. Similar Permian material has been described by Kùsta[42] from Bohemian material, and still more convincing traces of insect activities have been described by Kolbe[43] from borings of Upper Cretaceous wood from Syria (Curculionites), by Kolbe and Quenstedt[44] from Oligocene woods, and by Ponzi[45] from Pliocene woods.

[36] Williamson, W. C., Phil. Trans. Roy. Soc. Lond., vol. 171, p. 493, pl. 20, figs. 65, 66, 1880.

[37] Geinitz, H. B., Charakteristik der Schichten und Petrefacten des sächsischen Kreidgebirges, p. 12, pls. 3–6, 1842.

[38] Geinitz, H. B., Die Versteinerungen der Steinkohlenformation in Sachsen, p. 1, pl. 8, figs. 1, 4, 1855.

[39] Desmarest, E., Ann. Soc. Ent. France, 2e sér. tome 3, p. 26, 1845.

[40] Brongniart, C., Idem., 5e sér. tome 7, pp. 215–220, pl. 7ii, figs. 1-6, 1877.

[41] Brongniart, C., Idem., tome 6, p. 117, 1876.

[42] Kùsta, J., Sitz. k. Böhm. Gesell. Wiss. 1880, pp. 202–203.

[43] Kolbe, H. J., Zeits. deutsch. geol. Gesell. Jahrg. 1888, pp. 131–137, pl. 11.

[44] Quenstedt, F. A., Handbuch der Petrefactenkunde, 3 aufl. p. 482, pl. 37, 1885.

[45] Ponzi, G., Atti real accad. Lincei, 2 ser. vol. 3, p. 37, pl. 3, figs. 1–3, 1876.

DESCRIPTIONS OF PLATES XI–XIII ILLUSTRATING CHAPTERS II AND III

PLATE XI

PALEOZOIC EXAMPLES OF PARASITISM

The two upper figures are cystids showing pathologic encrustations possibly due to sponges. These cystids, primitive echinoderms, are known as *Holocystites canneus* and are derived from the Niagaran Limestone, Silurian of Jefferson County, Indiana.

The two lower figures show examples of two crinoids, *Aesocrinus magnificus*, with attached gastropods, forming a benign example of parasitism or dependent association which may have been the origin of certain forms of disease. The gastropod shells, attached over the anus of the crinoids, may be recognized as cap-shaped bodies to the left in each case. The specimens are derived from the Upper Coal Measures near Kansas City, Mo. The snail shells have the name of *Platyceras* and resemble somewhat the modern limpets.

All four specimens in Walker Museum, University of Chicago.

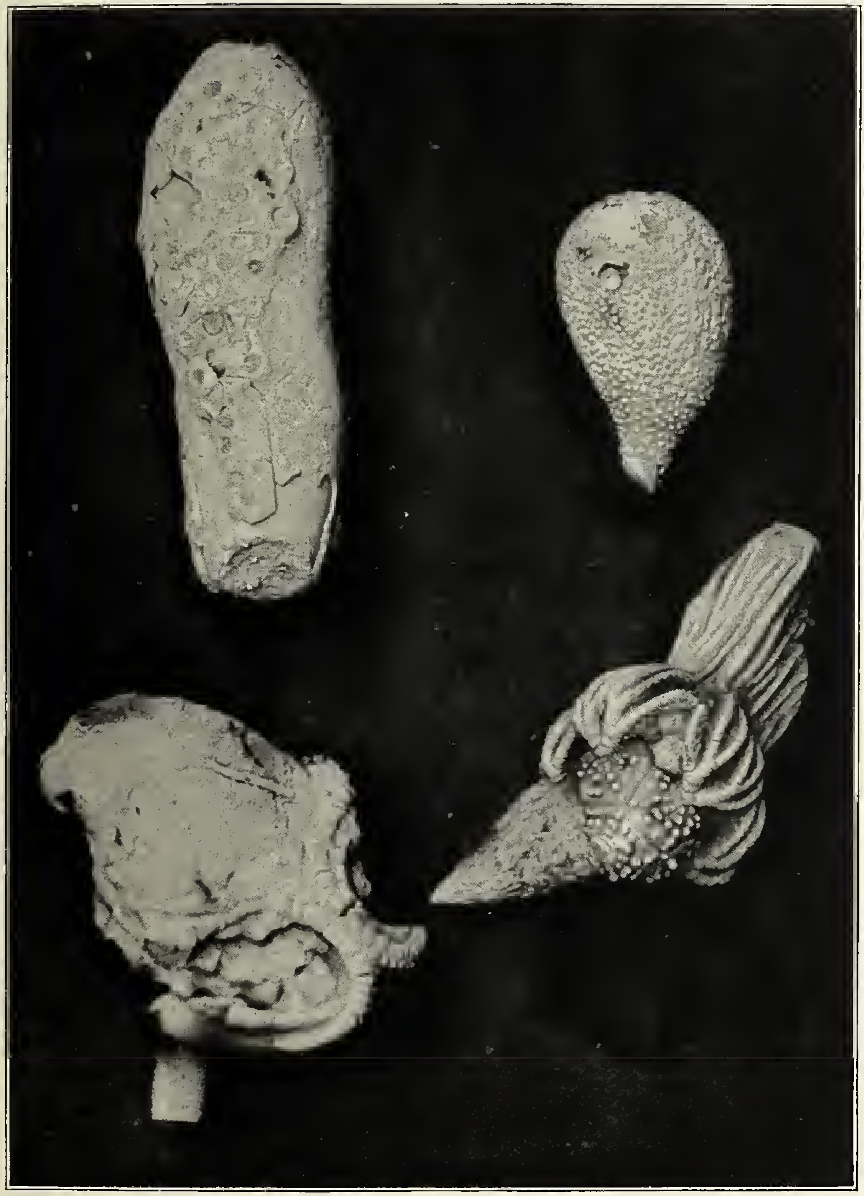


Plate XI

PLATE XII

PLATE XII

PALEOPHYTOPATHOLOGY

a. Gall from the Dakota sandstone, resembling oak-leaf gall. (Upper Cretaceous) (After Lesquereux).

b. Impression of *Ulodendron minus* L. and H. from the Carboniferous of England. (After Schenk.)

c. *Cladosporites fasciculatus* Berry on vessels of *Laurinoxylon* from the Middle Eocene of Texas. Fossil fungi. X 400 (After Berry).

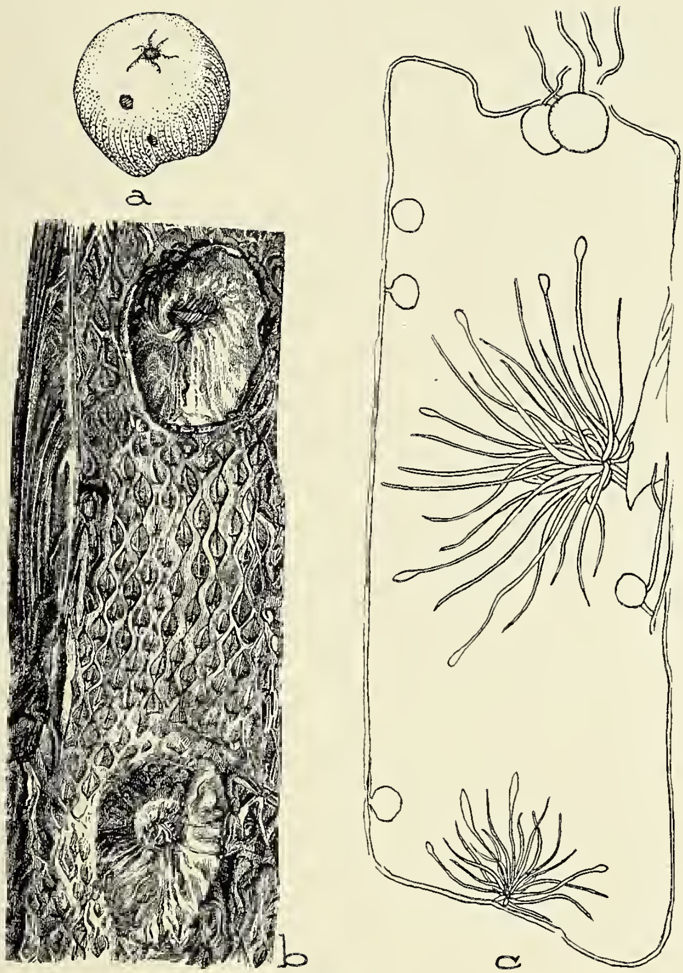


PLATE XII

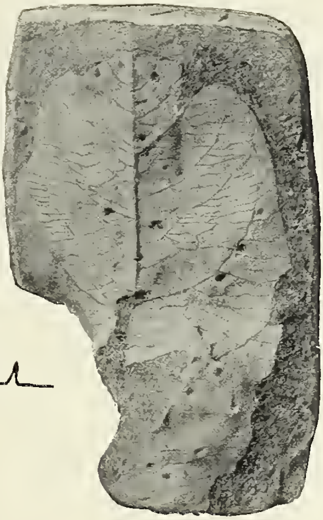
PLATE XIII

PLATE XIII

DISEASED FOSSIL LEAVES

a. Spot Fungus on a Lower Eocene leaf of *Diospyros*. (After Berry.)
b. Cone galls on a Lower Eocene leaf. (After Berry.)
c. Petiolar gall on a Lower Eocene leaf. (After Berry.)

a



b

c

Plate XIII

CHAPTER IV

CALLUS AND FRACTURE IN FOSSIL VERTEBRATES

The oldest known fractures. Histology of Permian fractures. A Triassic fracture. Fracture and callus in the dinosaurs. Fractures among early mammals. Fractures among the Pleistocene mammals. Fractures in the American Bison. Descriptions of Plates XIV-XXVI and Figures 8 to 11 illustrating Chapter IV. Figures 8-11 and Plates XIV-XXVI.

Healed fractures accompanied by more or less callus with often extensive necrotic sinuses are fairly abundant among the known remains of extinct vertebrates, and numerous instances have already been cited in a discussion of previous studies on paleopathology. Every geological age from the Permian on has furnished examples of fractures afflicting various parts of the body. The limb bones, of course, are frequently broken but the most common type of fracture among extinct animals is in the ribs. A few skull fractures are known, but the shape of the skull of early vertebrates was so different from the human skull that we can form no comparison between them on the basis of the modern surgical work on skull fractures.

Some idea of the nature of untreated fractures and the enormous formation of callus in wild animals is to be had from a study of Duckworth's contribution (1912) on the natural repair of fractures in apes. In the Carnegie Museum at Pittsburg there is a gorilla skeleton presenting a huge callus on one humerus due to a bullet wound. Doubtless the degree of callus in lower and higher vertebrates is a matter of blood pressure. In the sluggish heterothermal reptiles it would be no hardship for them to stay in one place when injured, for almost any length of time. Their digestive apparatus required food only once every few weeks or days depending on the weather. But among the isothermal mammals with high blood pressure there is always considerable restlessness under restraint. In view of these considerations we can understand how the early reptilian fractures healed with so little callus, while the mammalian fractures often heal with considerable callus, since continued irritation of the wound results in the production of more callus. The formation of necrotic sinuses is another matter, though partly dependent on the movements of the wounded animal. If the skin were broken by the extrusion of a broken bone the ingress of infecting bacteria would ensue. This is doubtless what

happened in the long snouted phytosaur from the Triassic which suffered a skull fracture. The healing process was slow, with the formation of abundant callus and extensive necrotic sinuses which have burrowed their way through the surrounding bone. The following discussion will treat of the successive geological evidences of fracture and callus, beginning with the earliest evidences of such traumatism.

THE OLDEST KNOWN FRACTURES

An examination of the figure of the limb bone of the ancient reptile, *Dimetrodon*, (Plate XIV, b and XV, c) will show the nature of the oldest fracture and callus. The bone is the left radius and it is from the Permian of Texas. The specimen is the property of the University of Chicago and I am indebted to the late director, Dr. S. W. Williston, for the privilege of studying this interesting and important specimen.

Dimetrodon was one of the most bizarre of all the ancient reptiles, and they abounded in grotesque forms. This curious reptile was a slow-moving, harmless animal, though provided with a terrific set of long, sharp canine and incisor teeth. It lived possibly on land in the neighborhood of ponds and streams. The brain case is exceedingly small, the space being no larger than the ball of one's finger, in a skull twelve to fourteen inches long, so it could not have been very pugnacious though doubtless carnivorous in habit. The character which gives the form its oddity is the extreme extension of the vertebral spines, which in the middle of the back extended into the air for fully a meter. These spines were doubtless connected by a membrane, as indicated in the restoration (Fig. 8). These spines on a related form, *Edaphosaurus cruciger*, were provided with cross bars like the mast of a ship. The purpose of this curious development is wholly conjectural, although it has led some students to suggest an aquatic habit for the form. Case says regarding them:

> The elongate spines were useless, so far as I can imagine. It is impossible to conceive of them as useful either for defense or concealment, or in any other way than as a great burden to the creatures that bore them. They must have been a nuisance in getting through the vegetation, and a great strain upon the creature's vitality both to develop them and to keep them in repair. The genus succeeded despite of them, or perished because of them.

Gilmore[1] has described a mounted skeleton of *Dimetrodon* which exhibits several fractured spines, one of them with two fractures.

[1] Charles W. Gilmore: 1919. A mounted skeleton of Dimetrodon gigas in the United States National Museum with notes on the skeletal anatomy. Proc. U. S. Natl. Museum, 56, 525–539, pls. 70–73.

The left radius of one of these bizarre animals had in some way suffered a complete, though simple, fracture somewhat below the middle of the bone. The fracture line, sharply marked by some intermediary callus, is still clearly evident in a clean cut, almost straight line, running squarely across the body of the bone. The union is a good one, the bone having healed with little or no shortening. The resulting callus is not extensive and has not obscured the straight line of the fracture.

The limb bones of the great majority of the early reptiles were solid and all of the early fractures were simple ones. An X-Ray study of the bone (Fig. d, Plate XIV) has furnished no information about the nature of the fracture since the bone is infiltrated with iron from the Red Beds in which it was fossilized, and is thus impenetrable to the X-rays.

The callus is evident as a pronounced swelling on the bone. Its surface is smooth, being interrupted on one side by a vascular opening, possibly for an arteria perforans. The slight development of the callus may be accounted for from the probable sluggish habits of the animal and its undoubted inactivity subsequent to the injury.

A microscopical examination of a section taken from the line of the fracture reveals a highly vascular callus, the blood spaces being filled with matrix. The osseous trabeculae are pure white with an abundance of osteoid tissue. There are few evidences of lamellae and scattering lacunae whose length parallels the length of the trabeculae. Canaliculi are not evident. The line of the fracture, filled in life with intermediary callus of a cartilaginous nature, is in the fossil bone represented by a substance entirely different from the matrix filling the vascular spaces and from the osseous trabeculae. It may represent an imperfect fossilization of the calcified cartilage. Bodies resembling cartilage cells are evident at a magnification of 250 in the fracture line; but the substance is so distorted by calcite crystals that it is not possible to be sure.

Another example of a fracture from the same geological horizon, i.e., the Permian Red Beds of Texas, furnishes information with reference to an old callus, which it will be interesting to study.

The fracture, (Fig. d, Plate XV) is through a rib, or possibly one of the elongate vertebral spines of doubtless the same form, *Dimetrodon*, to which the left radius belonged. The callus is slight and is assuredly an old one, for the fracture had completely healed and there is no indication of intermediary callus.

A study of the microscopic section, made by the well-known petrographic methods, reveals many evidences of an old callus such as we are familiar with today. Osteosclerosis and osteohypertrophy are clearly indicated and are often seen in old calluses of modern times. The region in the lower part of the figure (Plate XVI) is interpreted as an osteosclerotic area, the conclusion being based on the absence of osseous trabeculae and the presence of a heavy deposit of calcium salts, or other inorganic substance. The white band running from right to left through the figure is a spicule of bone filling in a fissure in the splintered bone, thus indicating an approach to a green stick fracture. The bony nature of this spicule is easily established by the presence of osseous lacunae with slight canaliculi. The hypertrophied area is to be observed in the upper right hand portion of the figure. The interpretation is based on the presence of numerous well-developed osseous trabeculae. There is no evidence that the fracture was infected, necrotic sinuses being entirely wanting.

An extremely interesting fracture of a large vertebral spine of a Permian reptile is shown in Plate XV, a, and the nature of the ensuing hypertrophy is shown in Plate XXI. Since this fracture had become infected and developed a chronic osteomyelitis I have deferred detailed discussion of this object to Chapter VII, where it is discussed with other chronic infections.

A completely healed fracture of the fibula of *Edaphosaurus* is shown in Plate XV, b and the histology of the old callus is given in Plate XVIII, c and d. This case of fracture is interesting as an accompaniment of the incompletely healed radius (Plate XV, c) showing two stages in the healing of fractures in ancient times. Neither fracture had become infected, and both healed in an extremely fine condition. The fracture of the fibula, slightly oblique, occurred near the middle of the bone. Although the fossil bone has nearly the hardness of iron, material for microscopic sections was removed from the periphery of the callus and sections were made in the laboratory of the U. S. Geological Survey.

HISTOLOGY OF PERMIAN FRACTURES

The histology of this Permian callus is shown in Plate XVIII, c and d, where the photomicrographs are shown in comparison with more recent callus in an American bison from the plains of Kansas. The histology of Permian bones resembles more nearly that of older Paleozoic vertebrates than it does that of later Mesozoic forms in the

presence of abundant osteoid tissue which in modern human bones is so often an indication of pathology. It is not the case among Paleozoic bones, however, since osteoid tissue is the normal constituent of the bone and the pathological disturbances often result in the formation of Haversian systems. This has been noted in a modern femur of a bull-frog (*Rana catesbiana*) where the new cancellous bone in the repaired fracture[1a] is laid down with an arrangement similar to that seen in Haversian systems.

Seitz[2] has described the histology of the bones of fossil and recent reptiles, dealing fully with the Reptilia of the Mesozoic. His fourteen plates of photomicrographs furnish much data on the histology of normal fossil bone. His results have been confirmed by an investigation which I conducted[3] into the comparative histology of fossil bone. The material at my disposal consisted of some 150 microscopic sections of fossil bone ranging in age from the Silurian sharks, through the Devonian fishes, the reptilia chiefly of the Permian, Triassic, Comanchean, Cretaceous and Tertiary mammals, supplemented by a few slides representing Carboniferous fishes. Unfortunately I was unable to study the histology of the higher Carboniferous vertebrates. Sufficient was at hand however to show clearly the nature of the histology of fossil bone. Such a survey was very essential in order to interpret the histologic nature of fossil lesions.

The fact that osteoid tissue is abundant in the bones of fishes was known to Kölliker and other early writers in histology. Kölliker especially tells of his investigations into the histology of the skeletal elements of fishes of many genera. The osteoid tissue is not quite so abundant in the bones of reptiles as in fishes but is still an important constituent. The lacunae are always small, not much larger if any, than in human bone. The canaliculi attached to the spindle-shaped lacunae are always short and so far as I can determine they never anastomose in normal fossil reptilian bone. The canaliculi seldom branch and end blindly in the osteoid tissue. Often, as many students

[1a] J. S. Foote. 1916. A Contribution to the Histology of the Femur. Smithsonian Contributions to Knowledge, xxxv, No. 3, pl. 1, fig. 5.

[2] Adolf Leo Ludwig Seitz. 1907. Vergleichende Studien ueber den mikroskopischen Knochenbau fossiler und rezenter Reptilien und dessen Bedeutung für das Wachstum und Umbildung des Knochengewebes im allgemeinen.

Nova Acta. Abh. der Kaiserl. Leop.-Carol. Deutschen Akademie der Naturforscher. Halle. Bd. LXXXVII, nr. 2, pp. 1–145 (230–370), Taf. XI–XXIV.

[3] Histology of the Elements of the Haversian System in Fossil Normal and Pathologic Bone. 56 pp. 14 plates. Prepared for the Williston Memorial Volume, but not yet published.

have shown, these lacunae and the canaliculi contain bacteria, chiefly those of decay. This subject, illustrated by photomicrographs is discussed at length in Chapter IX, dealing with the bacteriology of past geological ages. In normal fossil bone the lamellae are seldom evident but under pathologic conditions they become prominent. The interstitial cement seems to hypertrophy under diseased states. Perforating fibers of Sharpey are known in Cretaceous mosasaurs, but there seems to be from present evidence, no definite progressive states in the evolution of the histology of bone other than the gradual replacement of the osteoid tissue by lacunae, canaliculi and lamellae. This is of course the same sort of evolution as is evidenced by external form, but the transitions are less abrupt.

The histology of the bones of Permian reptiles, and those of later ages as well, seems to be characterized also by the presence of abundant large vascular channels which are exaggerated in pathologic states. Around these large canals, which may be considered as primitive Haversian canals are arranged the lamellae carrying the lacunae which they parallel. Such a condition is shown in Plate XVII, b, c and d. These figures represent the histology of the callus near an old fracture of a rib (shown in Plate XV, d) and illustrates well what I have said about Haversian arrangements following injuries. A similar condition is observed in pathologic mosasaur bones from the Cretaceous. In no case among fossil reptilian bone, either normal or pathologic, has an anastomosis between the canaliculi of adjoining lacunae been demonstrated. For this reason I have used the term *pseudo-Haversian* for these systems which seem incomplete, using an Haversian system as seen in a modern human femur as a type. The origin of the Haversian system has been previously discussed[4] and it will not be necessary to repeat here the facts concerning this matter. Arey[5] has also discussed the general nature of the Haversian system, thus adding data to the discussion of the histology of bone begun by Kölliker.[6]

We may summarize the histology of Permian reptilian bones by saying that the lacunae are few, small, and widely scattered throughout the osteoid substance. The canaliculi are short and unbranched

[4] Roy L. Moodie, 1920. The Nature of the Primitive Haversian System. Anat. Rec., xix, no. 1, 47–50, 1 pl.

[5] L. B. Arey, 1919. On the presence of Haversian Systems in membrane bone. Anat. Rec., xvii, 59–62.

[6] A. Kölliker, 1857. On the different types in the microscopic structure of the skeleton of osseous fishes. Proc. Roy. Soc. London, ix, 656–668.

and lamellae are chiefly evident in pathologic bone. Perforating fibers have not been seen in Permian bone.[6a]

By referring to the Tabulation of Geological Evidences it is to be seen that the age of these fractures, if measured in years, is something like 20,000,000 years. A comparison of the healing processes of these ancient bones with modern fractures reveals the interesting fact that nature established, in the early periods of vertebrate development, a method for the repair of fractures which prevails today.

A TRIASSIC FRACTURE

There existed during the Triassic, the opening period of the Mesozoic, a group of aquatic reptiles, known as the Phytosauria, in North America, Europe, and East India. These creatures had very elongate heads with nostrils set far back on the snout, just anterior to the eyes. The tip of the long snout was fitted with long teeth doubtless for the purpose of extracting food from the mud, into which it burrowed with its elongate snout. One of these creatures, either in a fight, or in turning a large stone for a wayward mollusc, had the misfortune to break his snout, and thus furnishes us, many millions of years later, the opportunity of studying the nature of an infected fracture.

This interesting lesion (Fig. c, Plate XXVI) is through the anterior end of the skull, just in front of the nostrils, of *Mystriosuchus Plieningeri* described by von Huene (1911) from the Triassic (Stubensandstein) of Aixheim, Germany. Von Huene's description gives a good idea of the details of the lesion.

> Anterior to the nostrils there is a deep oval, abnormal depression, due to the injury, around which the bony surface drops off sharply. It extends in length 8 cm. by 4.5 cm. wide from the anterior border of the right nostril to the right maxilla. Since the septomaxilla and the nasals of the right and left halves of the skull have at this place an unusual width, with remarkable dimensions, the injury must have been received during the youth of the animal, long before growth ceased. As the skull was being freed from the matrix there lay in the depression a siliceous pebble which exactly fitted the opening, and which it was necessary to break in order to remove it. But I do not believe that this pebble was the cause of the injury since it is exactly similar in all its characters to another pebble found near the right pterygoid process of the basisphenoid. There are similar objects scattered throughout the entire block of stone, and the matrix was more or less silicified. The siliceous pebble and the silification of the stone are secondary matters. I can only account for the injury by assuming that it may have been caused by a falling or rolling stone from some hillside which broke the snout while the animal was still young.

[6a] In the preparation and study of the microscopic anatomy of fossil bone, described in this volume, aid was rendered by the National Academy of Science and the American Association for the Advancement of Science, both of which organizations made grants to aid in preparing sections and for making photomicrographs.

On the dorsal surface of the skull there is an extensive semicircular necrotic sinus, with the surrounding surfaces carious. The lesion is available for study only through von Huene's descriptions and figures and a microscopical examination is not possible at present. The skull is in the museum of geology at the University of Tübingen, Germany.

Huene's photograph is given in Plate XXVI, c. The lesion is not very clear in the photograph, but Abel has given a pen drawing which shows something of the nature of the pathology. Abel's deductions[6b] regarding the possible pathological nature of the more anterior swelling (Plate XXVI, c) are extremely interesting and if correct widen the scope of paleopathology considerably. The curious eminences on the snouts of the parasuchians have been well known to students of vertebrate paleontology for a long time but no one has before attempted a solution of their nature. Abel now suggests that they are wounds which are the results of bites (Bissverletzungen) received in fights, and since the male is the most pugnacious of modern similar reptiles, the skulls showing these fossil eminences are the skulls of males. He supports his conclusions by comparisons with modern reptilia, long-beaked birds, and beaked mammals.

The eminences do not all occur in the same situation on the snout of the parasuchians, and there may be more than one; but curiously enough they usually occupy the median line of the skull. They do not have all the external appearances of pathological lesions of a traumatic nature and until they have been more carefully studied from the pathological viewpoint we cannot be sure that Abel is right, though his deductions appear sound. He concludes that many genera and species of Phytosauria have been established on the basis of pathologic skulls. If this proves to be true it will indeed be an important addition to our conceptions of paleopathology.

FRACTURE AND CALLUS IN THE DINOSAURS

The dinosaurs were the most characteristic reptiles of the Mesozoic. Their world-wide distribution, their diversity of form among the scores of species known, their gigantic size and the causes of their extinction have appealed to the imagination of the scientific paleontologist and to the general student of biology. No group of extinct vertebrates is so widely known among the reading public. The remains (Plate XXVIII) of these creatures are exceedingly abundant and no

[6b] O. Abel: Die Schnauzenverletzungen der Parasuchier und ihre biologische Bedeutung. Paleontologische Zeitschrift, Bd. V, Heft 1, pp. 26–57, figs. 1–10, 1922.

natural history museum is complete without some representation of their bones. The weathered fragments of the gigantic vertebrae and limb bones furnished the sheep herders of Wyoming materials for the erection of their winter cabins. The scarcity of evidences of disease among these ancient reptiles is noteworthy but occasional individuals show evidences of injury and disease. The discussion of fractures in their skeletons will be given here. Elsewhere (Chapter V) is given an account of the tumors and arthritides of the dinosaurs. The necroses are discussed in Chapter VII.

An enormous fractured rib (Plate XXIII, d) of one of the most gigantic dinosaurs, *Apatosaurus*, is on exhibition in the Field Museum of Natural History in Chicago. This lesion has been referred to by Riggs (1903), who says:

> The right member of the fifth pair of ribs is of interest in having an enlargement in the shaft due to an imperfectly healed fracture. The adjoining rib has a similar fracture which failed to heal.

It must have taken a terrific blow to have produced the fracture of these two ribs and could only have been inflicted by another dinosaur. The lesion was not infected since there are no necrotic sinuses. The fracture was a simple one as the bone was solid and healed with the production of only a moderate amount of callus.

The limb bones of the huge reptiles of the Mesozoic were seldom fractured, because of their great size and strength. A single limb bone of one of the largest dinosaurs has a length of six feet and a weight, as fossilized, of about 700 pounds. But one of the horned dinosaurs of the Edmonton Cretaceous of Canada, discovered by Barnum Brown and preserved in the American Museum of Natural History, had suffered an oblique fracture of the humerus which healed in a very bad way, because of an intense infection. The infection produced one of the sickest looking fossil bones known. On the anterior surface of the bone the periosteum had doubtless been greatly elevated by an ingrowth of callus, which later ossified into a bridge of bone connecting the lower articular surface with the enormous deltoid crest, and covering an enormous abscess, capable of holding several liters of pus. This is the only known fossil example of a *subperiosteal abscess*.[7] There is no

[7] The normal form of the bone of this dinosaur is described by Barnum Brown, 1913. A new trachodont dinosaur, Hypacrosaurus, from the Edmonton Cretaceous of Alberta. Bull. Amer. Mus. Natl. Hist., xxxii, 403, with figures. The fractured bone exhibiting the subperiosteal abscess was an isolated left humerus. The abscess may have penetrated the pleural cavity since the lesion is on the medial side of the bone, adjacent to the ribs.

definite indication that the infection ever completely healed and the dinosaur doubtless had a huge sore discharging pus from his arm for many months and up to the time of his death. Besides indicating an interesting new type of pathology for Cretaceous reptiles this lesion also furnished undoubted proofs of the presence at that epoch of infective bacteria.

The right ramus of the jaw (Plate XXVI, a) of one of the three-horned dinosaurs, *Triceratops serratus*, (Figure 9) preserved in the Yale University Museum and derived from the Lance formation of Niobrara County, Wyoming, exhibits a healed fracture which has been accompanied by no callus. The jaw is slightly deformed, indicating poor alignment, and suggesting that the fracture may have been of the green stick type. Apparently all of the solid-boned reptiles had simple fractures and the line across the mandible indicates that this was of the simple type.

A broken and healed horn core of another three horned dinosaur (Fig. a, Plate IX) indicates something of the traumatic influences to which these animals were subjected. This specimen is in the U. S. National Museum and I owe the photograph to the courtesy of Mr. Charles Gilmore. Elsewhere (Chapter V) it is suggested that the large tumor in the tail of one of the sauropodous dinosaurs may be the result of a fracture.

FRACTURES AMONG THE EARLY MAMMALS

Broken and healed bones are very common among the fossil mammals and no attempt will be made to discuss here all of the known examples, but rather to select examples of typical fractures of succeeding geological periods. There is no reason to expect that traumatic influences among the early mammals were any different from what they are today among the feral ungulates and carnivores. Healing processes were likewise the same.

There have not been seen, so far as I can learn, any indications of traumatisms among the scanty remains of the small Mesozoic Mammalia, so we begin our discussion with *the ankylosed elbow-joint in an Eocene mammal, Ectoconus*. This arm, as preserved in the American Museum of Natural History, is that of a small, primitive, five-toed Paleocene ungulate. It had in life suffered a fracture of the left humerus immediately above the condyles, and the ensuing infection resulted in the coalescence of the articular end of the humerus in the olecranal fossa. A pseudarthrosis was formed between the fractured end of the

humerus and the radius, though some new joint surfaces occur also on the ulna. A similar fracture is described in the American bison at the end of this chapter. The joint surfaces, in *Ectoconus*, were dense and eburnated, recalling in their ivory-like consistency the eburnated surfaces in joint lesions of the so-called rheumatoid arthritis. The fracture had evidently been badly infected, for the whole lateral surface of the ulna is pitted with necrotic sinuses and roughened with carious bone. In fossilization the bones were all crushed flat, so a detailed study of the joint lesion would not reveal a great deal more than is shown in an external examination. The injury must have seriously handicapped the individual but it survived the infection since the lesions are well healed over. This is the oldest known ankylosed elbow joint, with an antiquity of millions of years.

Ectoconus was a herbivorous animal allied to *Phenacodus* and the above-described skeletal parts are derived from the Puerco Eocene of New Mexico. The arthritic lesions succeeding the fracture involved the humerus, radius and ulna. The head of the ulna is completely obliterated. New articular surfaces appeared likewise on the deltoid tubercle, which in this animal, is an inch and a half in length. There is a large, double necrotic sinus on the proximal end of the radius. This forms an excellent example of traumatic *arthritis deformans* in an Eocene mammal and the injury must have shortened the limb considerably giving the creature a lame, hobbling gait, probably it held the injured member in the air and ran on three legs when in danger, as modern mammals do. There is no evidence of a metastasis in the rest of the skeleton, the bones being perfectly normal.

The mounted skeleton of *Titanotherium robustum* (Plate XX), in the American Museum of Natural History, exhibits a right rib which had been fractured in life and healed with considerable callus and formation of carious bone indicating a severe infection. The surface of the callus is bumpy and irregular and has not aided greatly in strengthening the rib. There was probably a great amount of irritation to produce a pseudarthrosis. This is one of the oldest examples of fracture among the early mammals, the animal having been found in the White River Oligocene of South Dakota.

A much older fracture is that of the lower jaw of an Eocene Creodent, *Dromocyon vorax*, one of the primitive carnivorous forms. The specimen is preserved in Yale University Museum having been discovered in the Bridger Formation of Wyoming. The fracture has

healed nicely with but little callus, so that the line of the fracture is hardly evident.

Skeletons of a Miocene chalicothere, *Moropus*, (Fig. 10) from the Agate Spring Quarry of Sioux County, Nebraska, preserved in the American Museum of Natural History, present evidences of a considerable number of fractures, as if these curious clawed ungulates had been much addicted to severe contests with other large animals, or else the animal had been injured by a fall. One rib, a radius, an ulna, and a scapula (Plate XXII) all show evidence of fracture with some callus. The rib had apparently suffered a double fracture which healed nicely with very little hypertrophy of the bone. The other fractures were accompanied by considerable hyperplasia and the scapula had been infected.

The left tibia and fibula of *Aeleurocyon*, a primitive carnivore from the Miocene of Wyoming, preserved in the Field Museum of Natural History, shows an oblique fracture (Fig. b, Plate XXIII) involving both bones, as indicated by the arrows. The union was not a very good one since the lines of the fracture are still clearly evident. The fracture of the tibia was apparently accompanied by considerable infection since there is a large exostosis on the adjoining fibula and the surface of the tibia is very carious.

In the paleontological collections at Princeton University there are several calluses on the bones, produced by breaking during the life of the animal, and an especially interesting one is to be seen in the mounted skeleton of *Archæotherium*, an ancient pig-like animal from the Oligocene, where there is a pseudarthrosis.[7a]

No skull fractures are known among the early mammals so we can make no comparisons with modern traumatism. The brain cases of most of the early mammals were quite solid and well protected by muscles so that a very severe blow would be needed to produce a fracture and this could only happen to the smaller mammals, since the larger forms are largely immune. The horned ungulates did not appear until quite late in the Tertiary and no data are at hand for a discussion of broken horn cores.

FRACTURES AMONG THE PLEISTOCENE MAMMALIA

The mammals of the Pleistocene were the first to attract the attention of the early paleontologists and much has already been said (Chap-

[7a] W. J. Sinclair, 1921. Entelodonts from the Big Badlands of South Dakota in the geological museum of Princeton University. Proc. Amer. Philos. Soc.: LX, 467–495, figs. 1, 13, 21.

ter I) about the fractures and other injuries of the cave bears of Europe. More is known of the pathology of the Pleistocene vertebrates than of any other period with the exception of the Cretaceous.

The American mammoth was one of the most abundant forms of Pleistocene mammals and its remains, with related species, are found widely distributed from Alaska to Mexico, and from the Atlantic to the Pacific coasts. Nearly every-one has seen the bones of these elephants and they are common objects in all museums. Pathological conditions are relatively rare though something is known of the afflictions suffered.

A related elephant, the American Mastodon, *Mastodon americanus*, with almost as wide a distribution and of very common occurrence furnishes interesting data on the bone pathology of these large beasts. A particularly splendid skeleton from Otisville, New York, is preserved in the Yale University Museum. This individual had suffered a skull fracture of the left occiput. The line of fracture is evident (Fig. a, Plate XXV) as a long curved impression, which has slightly healed over. The left rear portion of the skull had, in life, evidently been split away and had subsequently fused fast without becoming infected. No callus is evident from external examination.

Some unknown cause, possibly connected with the fracture, though widely removed from it, has produced a local bone necrosis of the outer table and through it one is enabled to pass a hand into the diploic air spaces, which, in the elephants, are extremely large and separate the brain case very definitely from the outer table of bone. One is thus enabled to understand how these creatures could suffer severe skull fractures or necroses without danger of either cerebral hemorrhage or meningitis. The present animal may have been an old fighting male for he had suffered many injuries.

The xiphoid portion of the sternum is deformed and apparently pathological, though in view of the great variations and deformities seen in human sterna no cause can be assigned to the deformity in the fossil.

Two ribs, one on either side, had been fractured (Fig. 11). The fracture on the right rib was imperfectly healed and was accompanied by a large amount of callus, though evidently not infected. The fracture was a simple one, running squarely across the bone, the line of fracture still being a line of weakness.

The fracture in the left rib was possibly of the green stick type. The healing seems to indicate a split rib, with a large projecting spicule, a portion of which is lost, projecting over an intercostal artery.

The remarkable Pleistocene bone deposit at the Rancho la Brea of Southern California, described by Merriam, (1911) just west of the city of Los Angeles furnishes abundant evidences of traumatism. The fauna of these beds is a very varied one, furnishing skeletons of wolves, lions, sloths, elephants, horses, camels, birds, saber tooth tigers, and many other forms. A graphic idea of how these animals became entrapped in the asphalt may be had by referring to the frontispiece of Scott's History of Land Mammals in the Western Hemisphere. Here is shown a fallen elephant, trapped in the asphalt, attracted thither by the water on the surface of the tar. Attacking and quarreling over the body of the elephant are wolves, some of them already caught in the tar, saber toothed tigers, while on a broken limb near by sits a large condor or vulture awaiting his turn at the feast. Animals are still trapped by the asphalt and when the writer visited the beds (Plate XLVII, a and b) there was a meadow lark caught on the surface of the tar, ready to begin the long process of preservation, to be recovered many thousands of years later. The encounters between the carnivores at the edge of the pool were ferocious. A skull of a young wolf the brain case of which is cut entirely through by the tooth of a tiger, the saber being broken off and imbedded in the preserved skull, is on exhibition at the University of California. Other animals (Plate LIII, a) possibly injured here escaped and later becoming entrapped furnish evidences of pathological growth. The skeletons of the saber toothed[8] tigers were afflicted with a very severe form (Plate XLIII, d) of spondylitis deformans, the bones were broken and healed and all evidences attest a very active life for these predaceous carnivores.

Among birds the shank of a crane has been broken and in healing had become deformed, with the production of considerable callus.

> Growths of diseased bone are seen not infrequently in the large wolves, where they are found in practically all parts of the skeleton and may suggest a decadent condition of the species in general. The most remarkable case is that of the hind foot of a wolf, in which the four bones supporting the toes have grown together and their upper ends are covered with a voluminous pathological bone growth. Another interesting case cited by Mr. Miller is that of an eagle in which the middle of the shank became so diseased that the end of the foot was lost entirely. Merriam.

During the Pleistocene there lived in North and South America a group of peculiar, gigantic ground sloths, known as megatheroids. They are supposed to have used their enormous fore claws for excavating trees so as to feed upon the tender foliage. This deduction is based

[8] More fully described in Chapter V.

on a study made by Sir Richard Owen[9] in 1842 on the skeleton of *Mylodon robustus*, from the Pleistocene deposits of South America. Owen studied the fracture very carefully and concluded that it was produced by the falling of a large tree which the animal had uprooted with its gigantic claws.

The fracture was extensive and affected only the outer table of bone, which in these large sloths as in the elephants was separated from the inner table by large diploic air spaces. Carious roughening of the adjacent bony surfaces indicates infection and the formation of osteophytes points to a considerable duration of the healing process. The fractures were directly over the brain and though the creature was probably stunned and temporarily disabled by its reception it was able to recover itself, for the wound was well healed over. In view of Owen's deduction from this fracture these huge megatheroids are always mounted in museums in conjunction with trees.

A beautiful skull of an extinct musk ox, *Symbos cavifrons*,[10] from the Pleistocene shows on the left side of the face an enormous injury (Plate XXVI, b) leading into the maxillary sinus, produced possibly in a fight and resulting in a chronic, suppurating sinusitis due to infection following the injury. The margin of the bone is slightly healed over and a moderate number of osteophytes were formed.

FRACTURES IN THE AMERICAN BISON

Remains of the American bison (Plates XXIV, LVI, LVII) found scattered over the western plains, may well be regarded as those of an extinct race and for that reason a short discussion, with illustrations, of the species is given in this work. The skeletal remains on which these observations were made were assembled more than 50 years ago at the University of Kansas when the bison still existed in a wild state. The elements studied consist of a femur, a radius and ulna, a metacarpal, an infected knee joint, a thoracic vertebra and a part of a humerus. Many of them show interesting types of fracture (Plate XXIV), but

[9] Sir Richard Owen, an English anatomist and paleontologist, 1804–1892. An eminent student of vertebrate paleontology, especially noted for his studies on the reptilian faunas of the Permian and Triassic of South Africa, for his discoveries in the Cretaceous, Pleistocene, and other geological periods. His description of the megatheroid quadrupeds is one of the most famous in the annals of paleontology, as was his deduction as to the life habits of the giant sloths from a study of the Pleistocene fracture above described. A voluminous writer, Owen's contributions occupy a high place in paleontological literature.

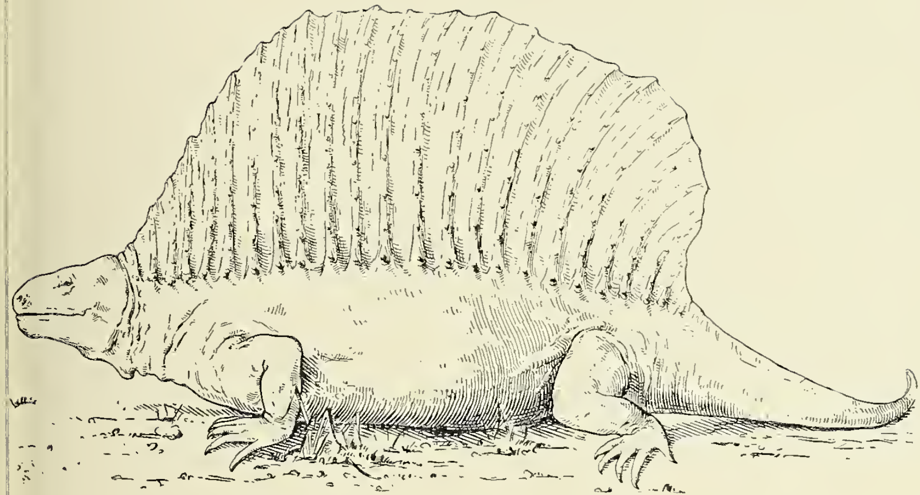
[10] E. C. Case: On a nearly complete skull of *Symbos cavifrons* Leidy from Michigan. Occasional Papers of the Museum of Zoology, University of Michigan, Ann Arbor, No. 13, 1915.

the knee injured by a leaden bullet, which still remains as a sequestrum, had developed a huge osteomyelitis, and discussion of this specimen is given in Chapter VII. The humerus shows arthritic lesions; the metacarpal an osteomyelitis, the thoracic vertebra had been injured and the femur exhibits an interesting pseudarthrosis (Plate XXIV). The fracture was a complete one and oblique, severing the bone near the lower articular surface. The animal was forced to move around in order to avoid being devoured by wolves or shot by hunters and the enforced activity produced a huge callus which never completely ossified, so the animal died before the wound was completely healed.

DESCRIPTIONS OF FIGURES 8-10 AND PLATES XIV-XXVI, ILLUSTRATING CHAPTER IV

FIGURE 8

Restoration of *Edaphosaurus cruciger* based on skeletal material discovered in the Permo-Carboniferous Red Beds of Archer County, Texas, by Dr. E. C. Case. The reptile was a highly specialized creature, sluggish in movements, and entirely harmless, living perhaps on molluscs, insects, and vegetation. The restoration is introduced here since it is probable that the fractured spine showing the old callus came from one of these animals. A fracture of the spine, it may be seen, was easily produced. The animal reached a length of about two meters.



FIGURES 9-10

FIGURE 9

A life restoration of *Triceratops elatus* Marsh from the Cretaceous of North America as modeled in the United States National Museum by Charles W. Gilmore, based on a mounted skeleton. One-fortieth natural size. The pathology of this curious reptile is given in the accompanying pages.

FIGURE 10

Model of *Moropus elatus* as preserved in the Carnegie Museum at Pittsburgh, representing the animal at one-thirtieth natural size. Described by Holland and Peterson, Memoirs Carnegie Museum, III, plate LXXVII.

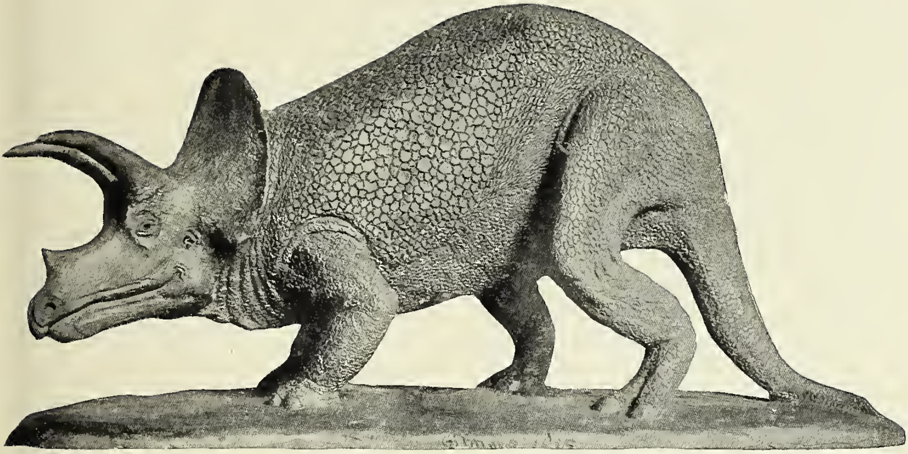


Figure 9

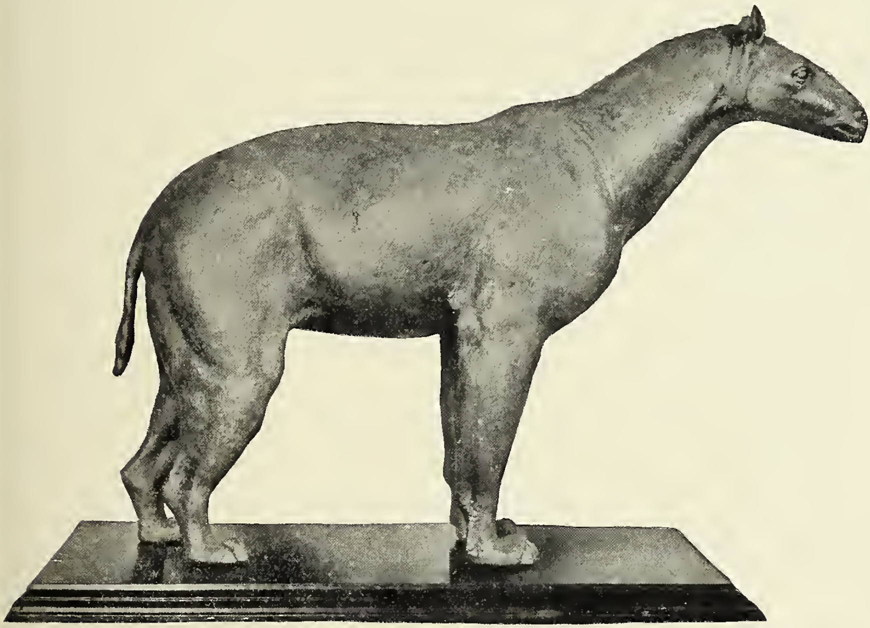


Figure 10

PLATE XIV

PLATE XIV

THE OLDEST KNOWN FRACTURES

a. Skeleton of a long-spined reptile from the Permian of Texas, *Edaphosaurus'* as mounted by Paul C. Miller in Walker Museum, University of Chicago. The different parts of the skeleton were found more or less commingled in the Brier Creek bone-bed. The distal part of the tail and the feet are restored from allied animals. The skull is modeled from a perfect specimen. Under the direction of Dr. S. W. Williston. A restoration of the animal is shown in figure 8.

b. Photograph of the radius of an allied animal, *Dimetrodon,* showing an example of the oldest known fracture. This bone is also shown in Plate XV, c.

c. Normal right arm of *Ophiacodon mirus,* a Permian reptile related to *Dimetrodon,* showing form of normal radius and relative position of bone in fore-arm. The fractured radius (shown in *b*) was found isolated so we do not know whether the ulna was injured or not. Photograph by S. W. Williston of a specimen mounted in Walker Museum, University of Chicago.

d. Radiograph of bone shown in *b.* The white line near the letter *d* is a post-fossilization fracture.

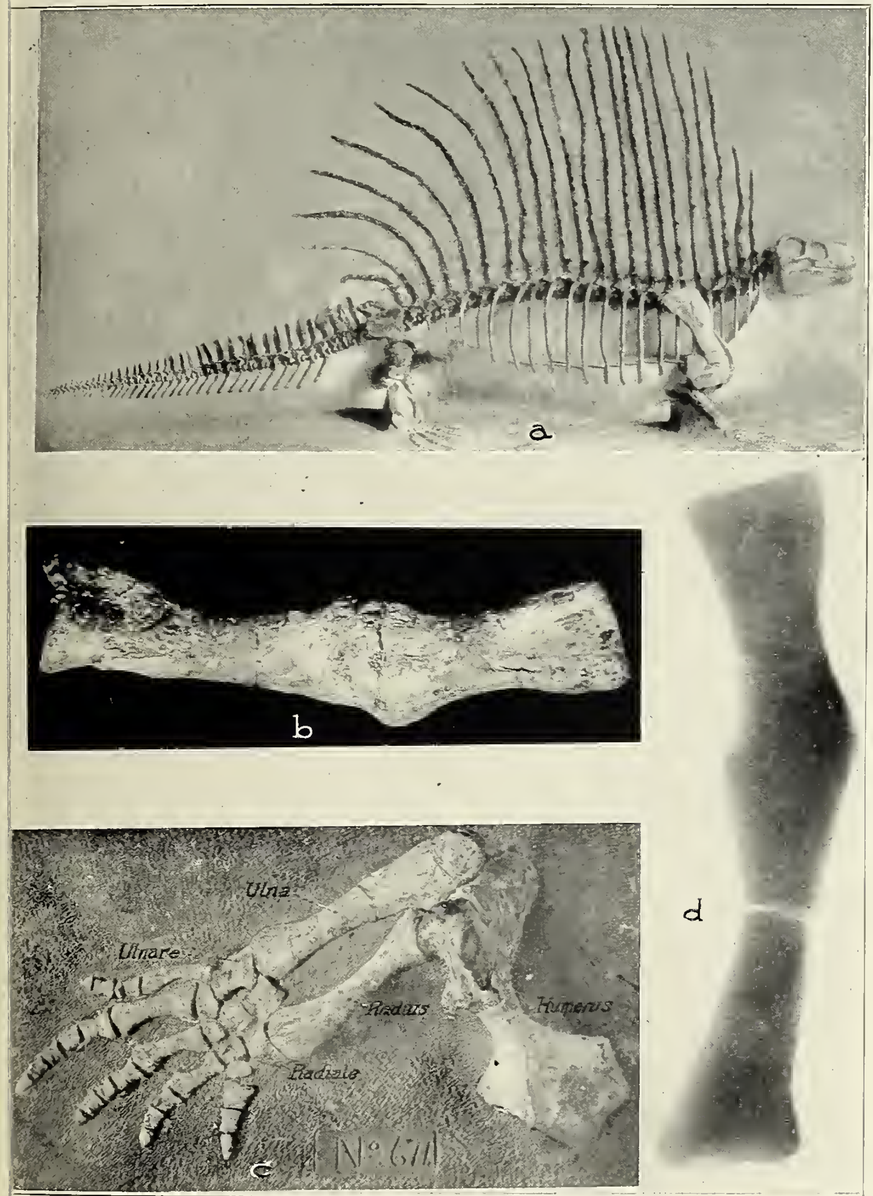


PLATE XIV

PLATE XV

PLATE XV

EXAMPLES OF PERMIAN PATHOLOGY

a. The oldest known example of osteomyelitis. Fractured vertebral spine of a Permian reptile (*Dimetrodon?*) from Texas showing, at the arrow, the line of fracture. The fracture became infected, for the bone is greatly roughened and there developed an osteomyelitis (see Plate XXI) which is evident in the swelling above the line of fracture. The sinuses, in life filled with pus, are represented in the fossil by calcite-filled cavities, shown in Plate XXI. Collected by Paul C. Miller.

b. Fractured fibula of a long spined Permian reptile, (*Edaphosaurus?*, see Plate XIV, a) showing an old callus (see Plate XVIII, c, and d). Collected by Dr. E. C. Case from the Brier Creek bone-bed, Archer County, Texas, Wichita Formation, Permo-Carboniferous. Original in the University of Michigan.

c. Callus and fracture of the left radius of a long-spined reptile, *Dimetrodon*, a primitive tetrapod from the Permian of Texas. The original is in Walker Museum, University of Chicago. (See plate XIV, b and d.) Specimen loaned by Dr. S. W. Williston.

d. Portion of fractured spine (rib?) of a Permian reptile *Edaphosaurus?*, showing the callus. The specimen is three inches long, and was collected in the Permian of Texas by Mr. Paul Miller of the University of Chicago.

e. Fracture in an undetermined fragment of spine.

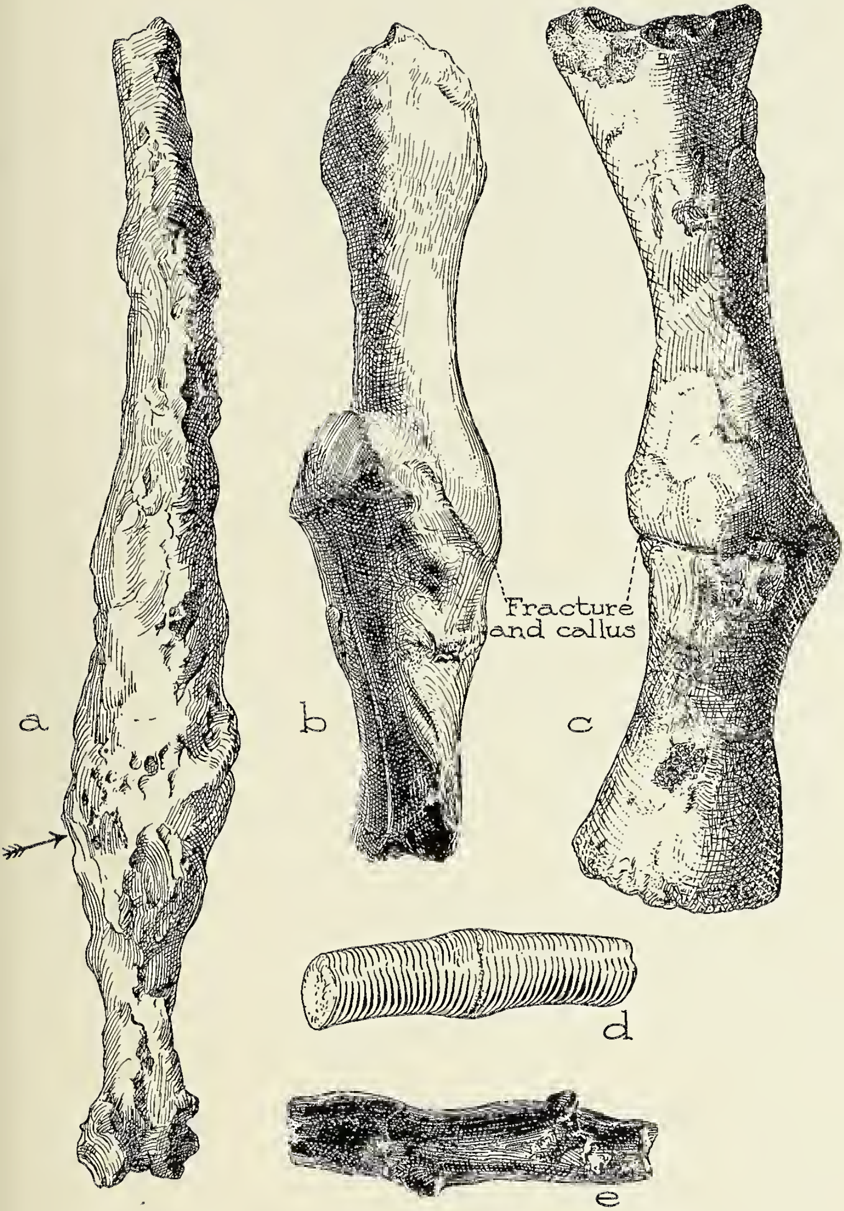


Plate XV

PLATE XVI

PLATE XVI

Microscopic section of callus and fracture on spine (rib?) showing, below, the osteosclerotic area, in the middle, the white spicule of bone running from right to left, and above, the area of osteohypertrophy. X 300.

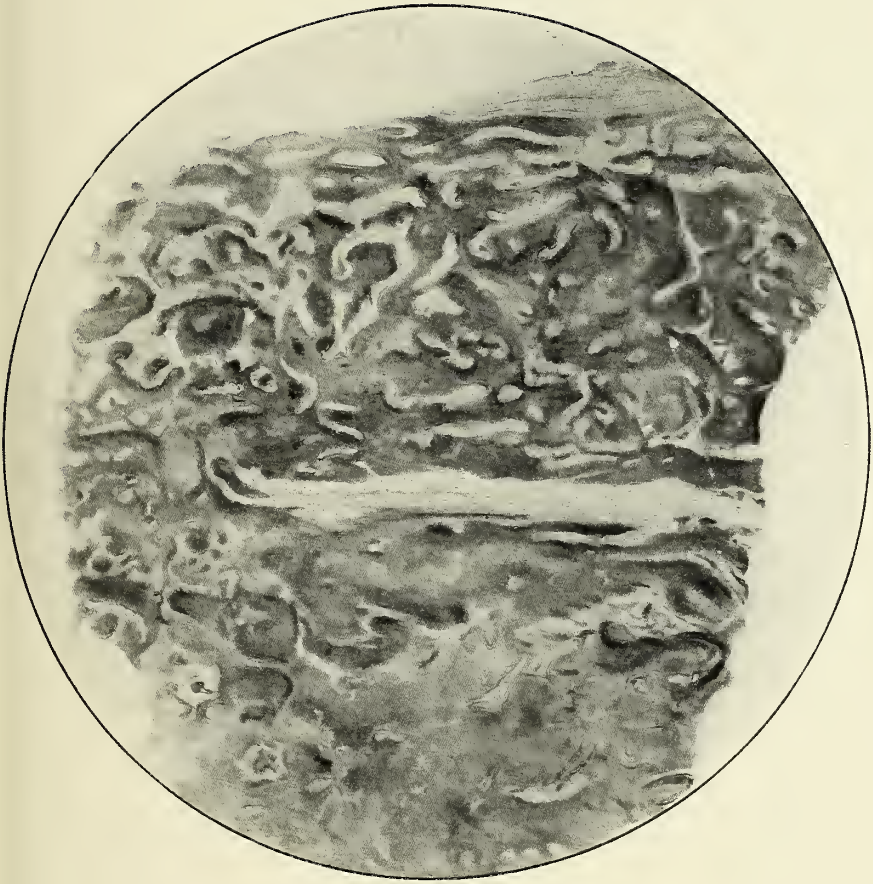


Plate XVI

PLATE XVII

PLATE XVII

Photomicrographs of histology of Paleozoic fractures compared with normal human bone.

a. Histology of human femur showing Haversian systems. X 70.

b. Histology of fractured spine of a Permian reptile of Texas, showing concentric arrangement of osseous lamellae around large vascular spaces. X 200. The tendency to form pseudo-Haversian systems in ancient pathologic bone is here clearly exemplified. Normal fossil bone seldom presents this appearance.

c. Portion of a fractured spine of a Permian reptile showing histology of bone near a callus. X 70.

d. An enlarged view of one of the pseudo-Haversian arrangements around a vascular channel in the same section. X 300.

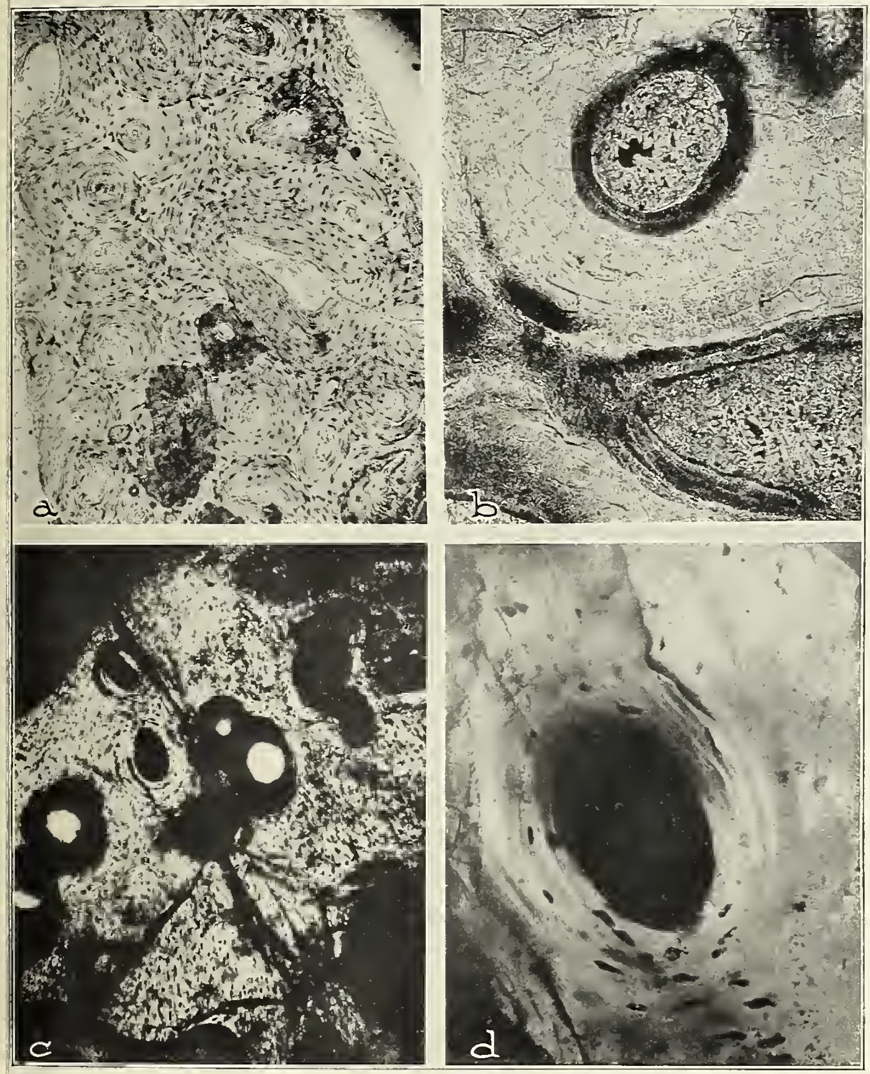


PLATE XVII

PLATE XVIII

PLATE XVIII

Photomicrographs showing histology of ancient fractures and infections, compared with recent bone.

a. Osteomyelitis in the metacarpal of the Bison from the plains of Kansas. X 70.

b. Osteomyelitis in the ulna of the American Bison from the plains of Kansas. X 100. Junction of pathological lesion with normal bone. Haversian canals in pathologic bone.

c. Callus in fractured fibula of *Edaphosaurus*, Permian of Texas. Original in the University of Michigan. X 70. See figure b, Plate XV.

d. Callus of fibula of *Edaphosaurus*, a spiny reptile from the Permian of Texas, showing arrangement of trabeculae of bone and distribution of vascular spaces. X 100.

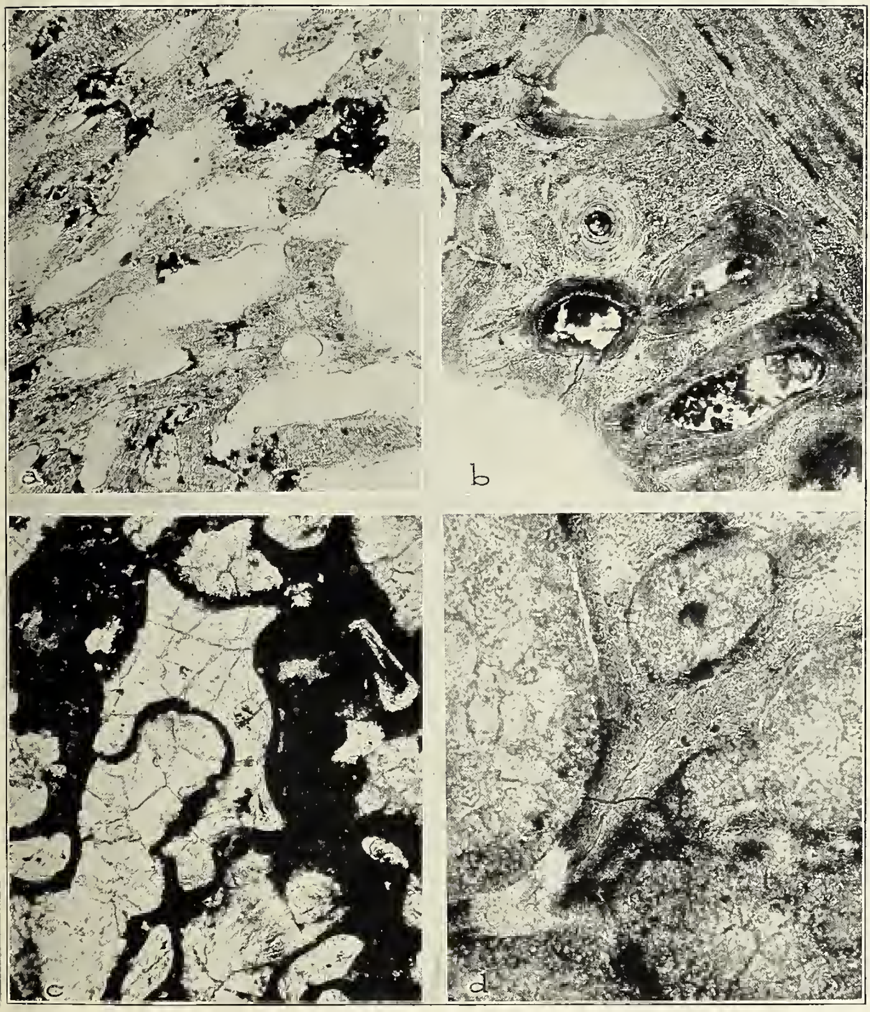


Plate XVIII

PLATE XIX

PLATE XIX

Photomicrographs of histology of normal and pathologic bone, human and American Bison.

a. Human femur, normal. X 300.

b. Callus in femur of bison from the plains of Kansas, showing Haversian systems. X 70.

c. Arthritis deformans in the humerus of the American Bison from the plains of Kansas. X 100.

d. Osteomyelitis due to bullet wound in the knee of an American bison. X 100.

The increased vascularity shown in c and d is to be noted.

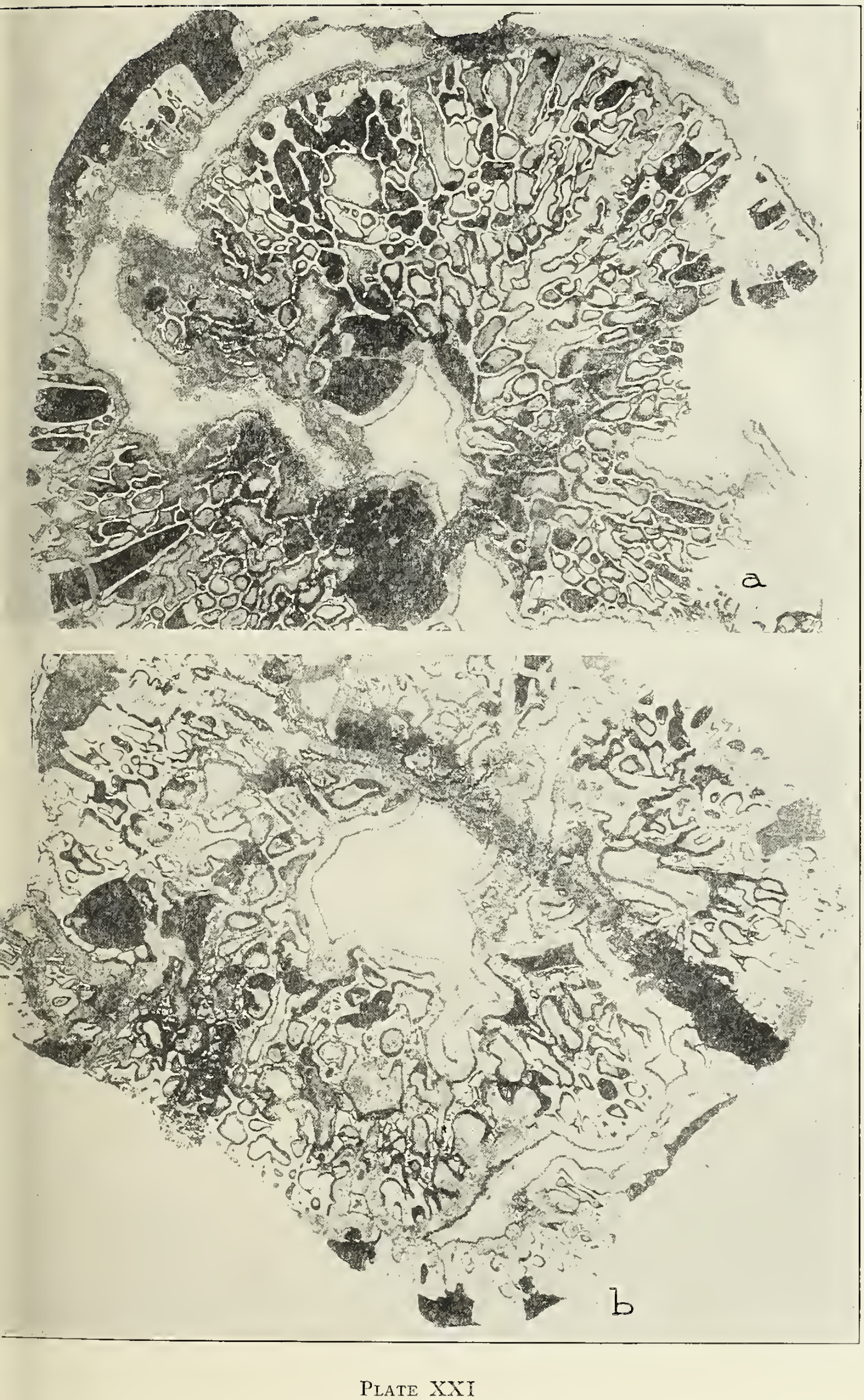


Plate XXI

PLATE XX

PLATE XX

The skeleton of an early Tertiary mammal, *Titanotherium robustum*, from the White River Oligocene of South Dakota, as it is mounted in the American Museum of Natural History. The fifth rib on the right side has been fractured and has healed with the formation of considerable callus and a pseudarthrosis. The details of the callus are shown in the enlarged sketch in the lower right hand corner, one-twelfth natural size. Courtesy of Dr. W. K. Gregory.

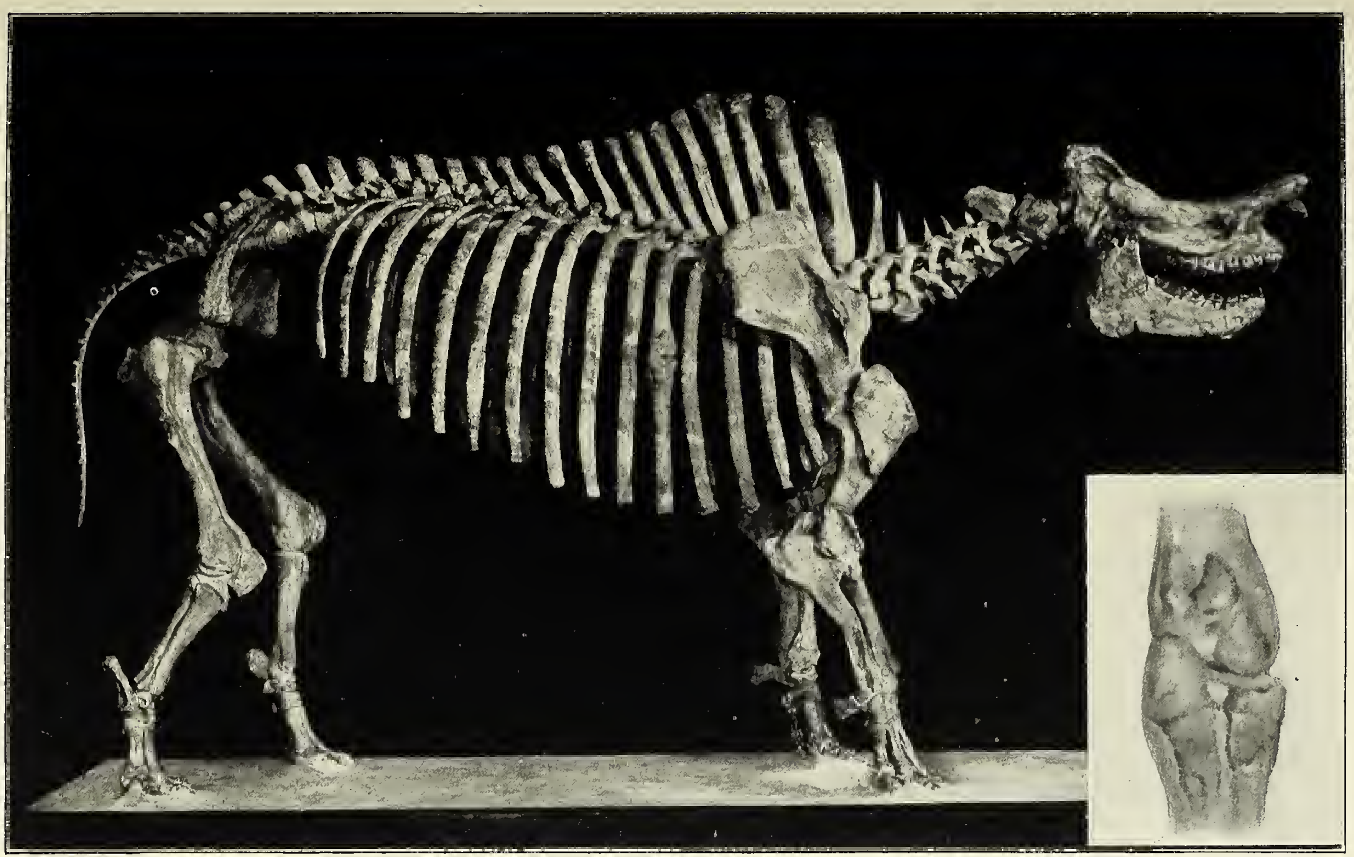


PLATE XX

PLATE XXI

PLATE XXI

A PERMIAN OSTEOMYELITIS

a. A cross section through the spine shown in Plate XV, a, immediately above the point of the arrow, showing the highly developed sinuses which in life were filled with pus. There is no indication of the sequestrum which doubtless caused the infection. It was perhaps located at a different level. X 10.

b. Section through the same spine at a lower level. X 10.

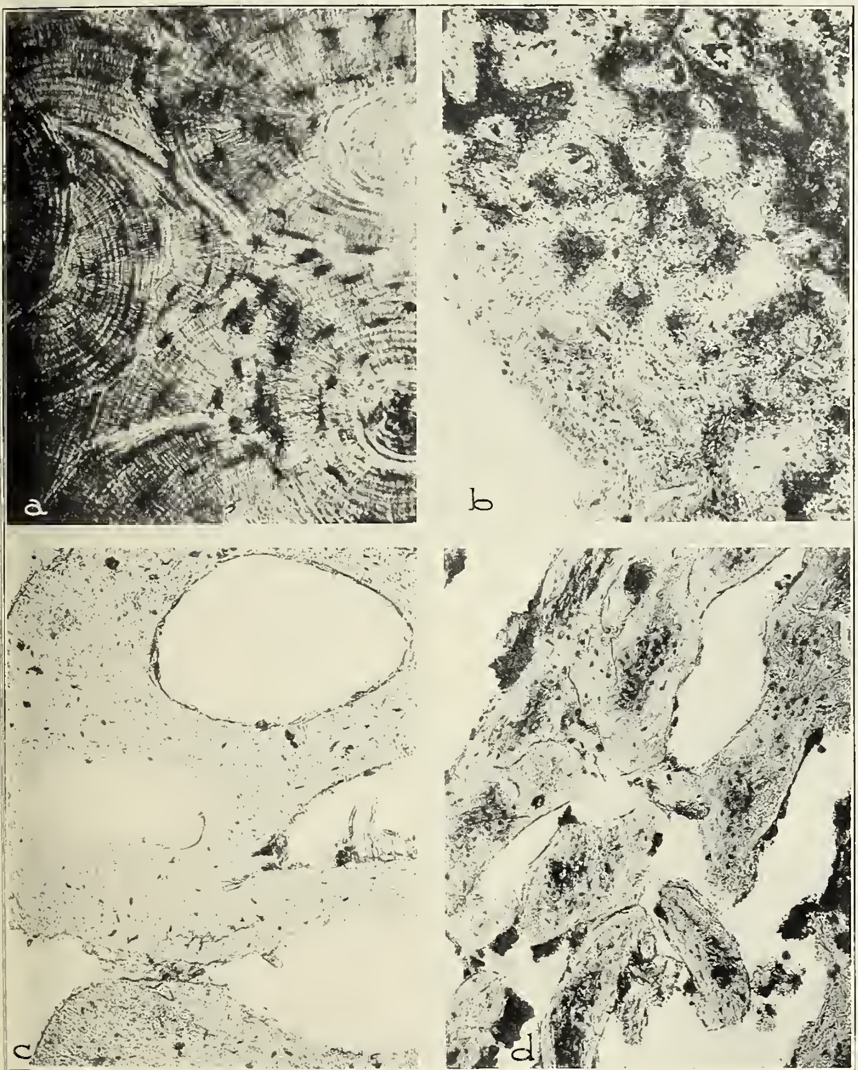


Plate XIX

PLATE XXII

PLATE XXII

FRACTURES IN MOROPUS

a. and b. Radius and ulna of *Moropus*, a large chalicothere, from the Agate Spring Quarry, Sioux County, Nebraska. Miocene, about 1,500,000 years ago. These bones, the normal forms of which are shown in the small inserts, were fractured during life and have healed with callus formation, and partial fusion of the bones, as well as some necrosis which indicates that the injury became infected. Exostosial growths are evident near the olecranal fossa.

c. Rib of same animal, fractured in two places and healed with only a slight deformation.

d. Scapula of same animal from above, fractured during life. *Moropus* was a large mammal, with somewhat the appearance of a horse, though the forelegs were longer than the hind legs, and all feet were provided with claws. The Chalicotheroidea are characteristic of the Oligocene and Lower Miocene. They have been extinct since Miocene times. Restoration of the animal is shown in Figure 10.

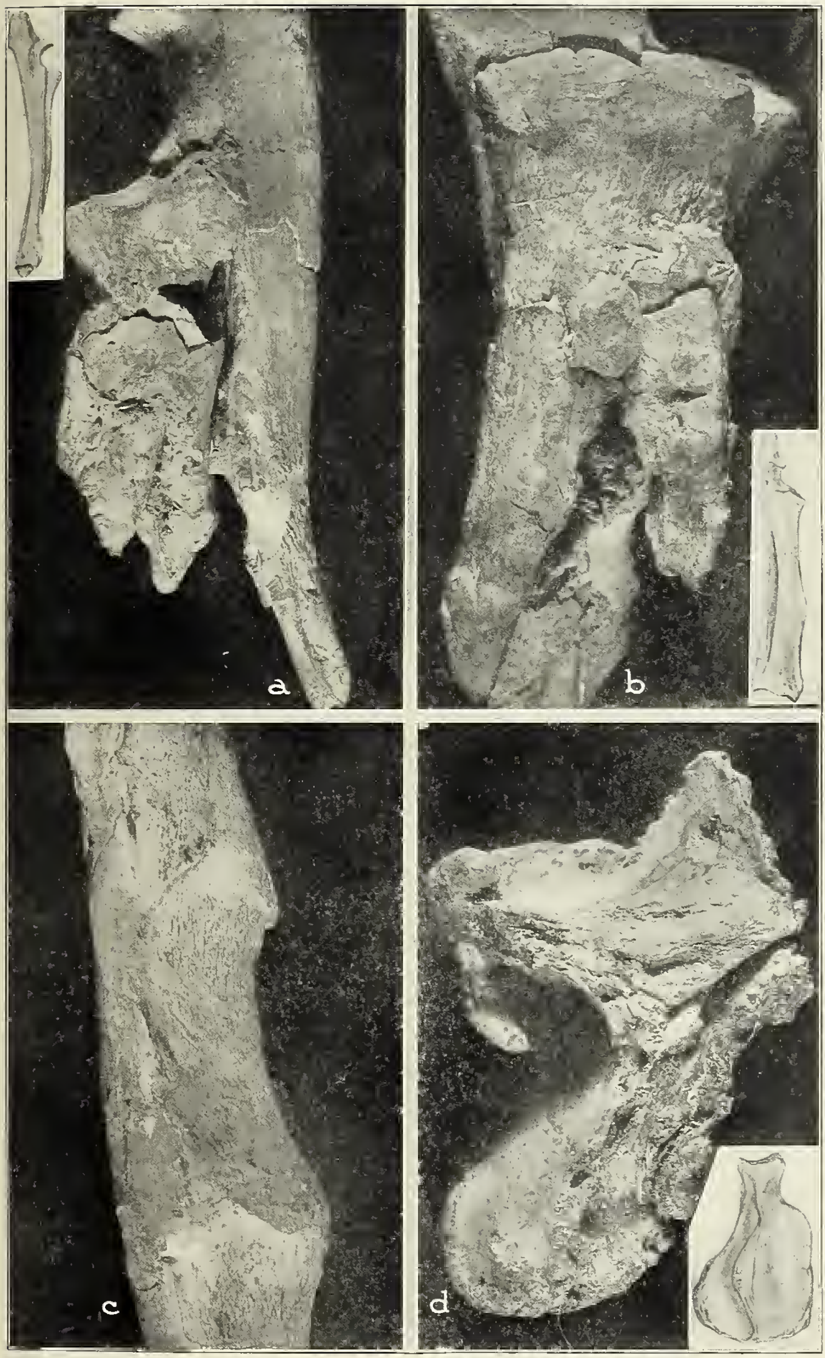


Plate XXII

PLATE XXIII

PLATE XXIII

TRAUMATIC LESIONS IN DINOSAURS AND IN A MAMMAL

a. Left scapula and coracoid of a carnivorous dinosaur, *Antrodemus valens* Leidy. The upper end of the scapula had been fractured during life, as evidenced by the bifurcated and greatly widened upper end, as well as by the hypertrophy exhibited in the shaft which in the normal bone is more slender, the blade being uniform from the coracoid upwards. Comanchean of Garden Park, near Canon City, Colorado. Collected by M. P. Felch, in 1883. (After Gilmore.)

b. The left tibia and fibula of *Aeleurocyon*, a primitive carnivore from the Miocene of Wyoming, showing an oblique fracture involving both bones. Specimen preserved in the Field Museum of Chicago.

c. Caudal vertebrae of an English dinosaur, *Cetiosaurus leedsi*, showing arthritic lesions, similar to those described for *Apatosaurus* and *Diplodocus*. Specimens preserved in the British Museum. Drawn from a photograph published by Holland.

d. A fractured rib of one of the huge dinosaurs, *Apatosaurus*, shown in a mounted skeleton in the Field Museum of Chicago.

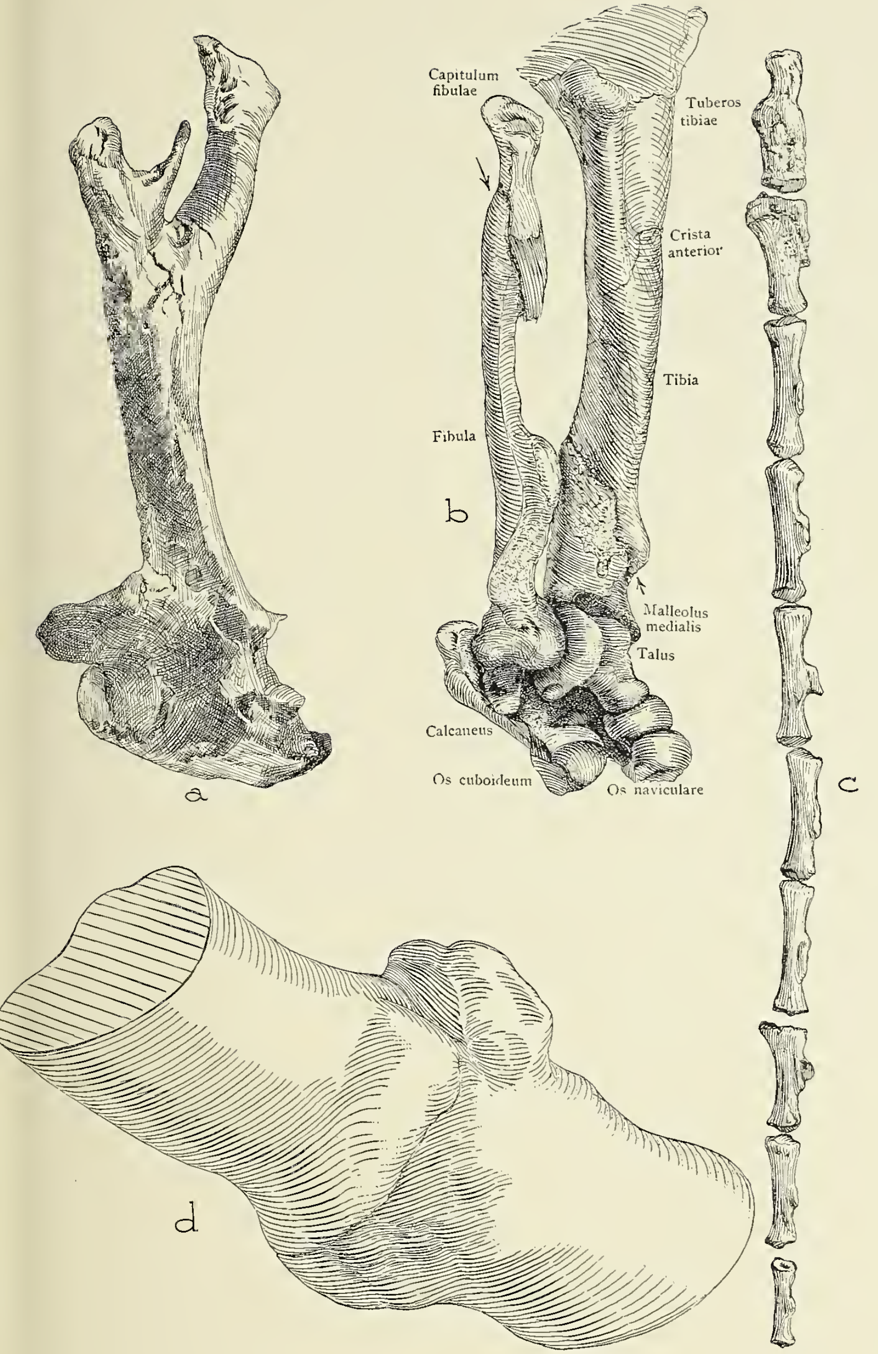

Capitulum fibulae
Tuberos tibiae
Crista anterior
Tibia
Fibula
b
Malleolus medialis
Talus
Calcaneus
Os cuboideum
Os naviculare
a
c
d

Plate XXIII

PLATE XXIV

PLATE XXIV

FRACTURE IN THE AMERICAN BISON

Fracture of the femur immediately above the condyles in the American Bison, from the plains of Kansas. Original in the University of Kansas. The huge amount of callus shown in the left-hand figure is due to the oblique fracture which became misplaced and formed a pseudarthrosis with one of the condyles of the femur, as shown in the right-hand figure. There was no infection.

Plate XXIV

PLATE XXV

PLATE XXV

FRACTURE IN THE AMERICAN MASTODON

a. Skull of a large Mastodon, showing in the posterior part of the head a skull fracture which had not healed. In the temporal fossa is a necrotic sinus. Original in Yale University Museum.

b. Fractured ribs of a Mastodon skeleton mounted at the University of Wisconsin.

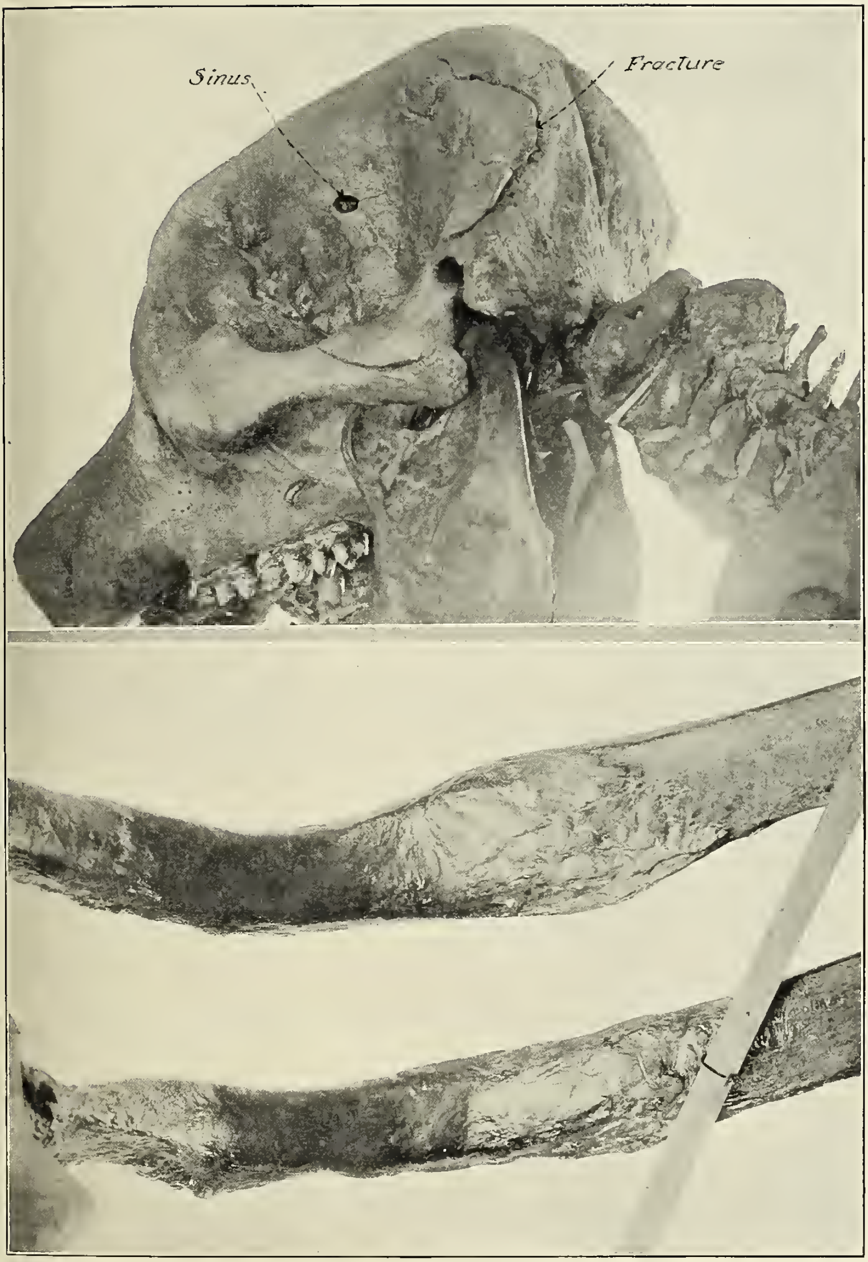


PLATE XXV

PLATE XXVI

PLATE XXVI

FRACTURE AND NECROSIS IN ANCIENT REPTILES AND THE MUSKOX

a. Fracture, at ☞, of the lower jaw of one of the large three horned dinosaurs, *Triceratops*, from the Lance Formation of Niobrara County, Wyoming. Specimen in the Yale University Museum.

b. Skull of a Musk-ox, *Symbos cavifrons*, possibly 80,000 years old, from the Pleistocene of Michigan, showing (at the arrow) a lesion possibly indicating a chronic suppurating sinusitis. The skull is preserved in the University of Michigan.

c. The skull of *Mystriosuchus Plieningeri* H. von Meyer, a parasuchian, from the Triassic of Aixheim, exhibiting a broken snout, with resulting callus and bone necrosis. This is the oldest known skull fracture. (After von Huene.)

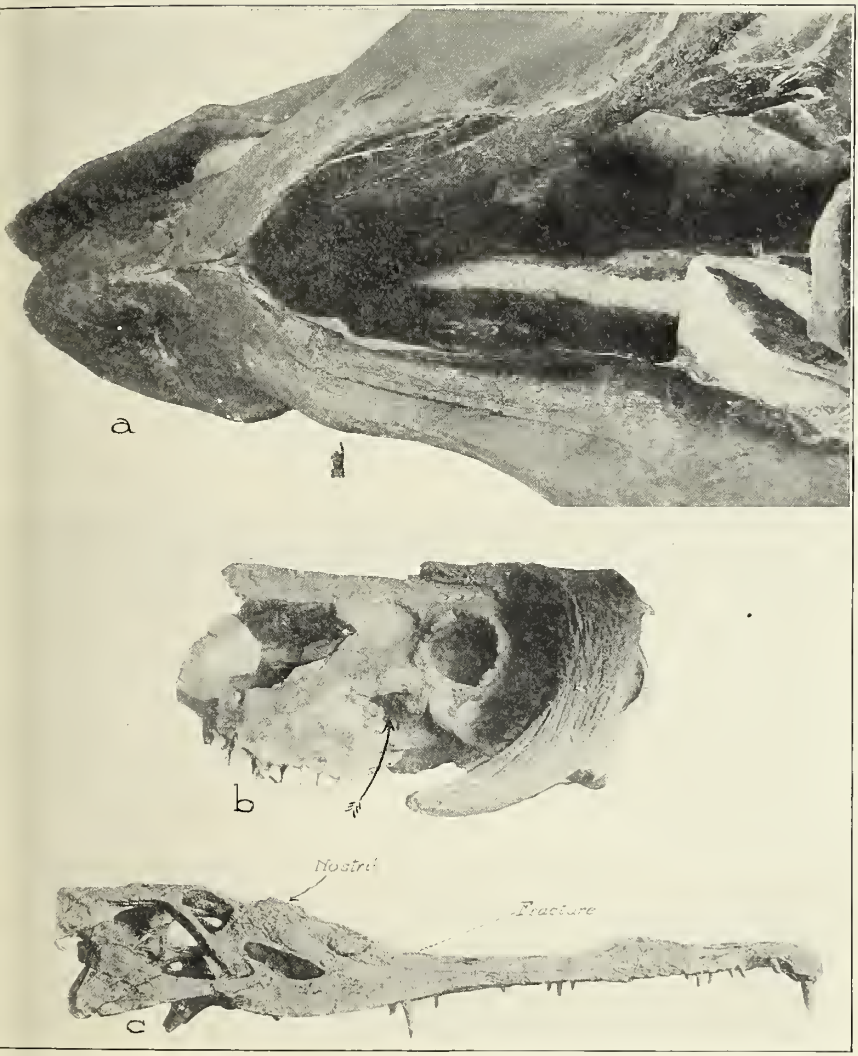


Plate XXVI

CHAPTER V

DEFORMING ARTHRITIDES IN THE EARLY VERTEBRATES

Arthritic lesions in the dinosaurs. Spondylitis deformans in the dinosaurs. The fossilization of blood corpuscles. Arthritides in the mosasaurs. Osteomata among modern vertebrates. Multiple arthritis in a mosasaur. Cretaceous osteoperiostitis with arthritic lesions. History of spondylitis deformans. Spondylitis deformans in a Miocene crocodile. Spondylitis deformans in a Pliocene camel. Descriptions of Figures 11–18 and Plates XXVII-XLIII illustrating Chapter V. Figures 11-18 and Plates XXVII-XLIII.

Deforming arthritides are fairly common among fossil vertebrates and indicate a variety of pathological conditions. These lesions represent diseased or traumatic afflictions of the intervertebral articular surfaces, the entire body of the vertebra, the vertebral ligaments, as in the cases of spondylitis deformans described among the Pleistocene mammals, the articular surfaces of the limbs and skull and all lesions associated with the joint surfaces.

The grouping is one of convenience and doubtless many of the lesions classified in this group should be placed elsewhere, but in view of the uncertainty of diagnosis the above plan will be adopted. Certain arthritic lesions are described elsewhere in the book and reference may be had to them through the index.

Arthritides are especially common among the Pleistocene mammals, though the history of the affliction is a long one. The arthritic condition sometimes spoken of as rheumatoid arthritides, noted by Virchow in the cave bears (1895), is also known to occur in a sub-fossil human skeleton (Parker, 1904) from Lansing, Kansas. An arthritis is certainly present in a Cretaceous mosasaur, where a well-developed osteoma accompanied the arthritic inflammation. Spondylitis deformans is extremely common among the cave-bears of Europe and the saber toothed tigers (Moodie, 1918.3) of California. These forms will be described as indicating this pathology on a later page.

ARTHRITIC LESIONS IN THE DINOSAURS

Our knowledge of the anatomy and relationships of the dinosaurs is largely due to the studies of Marsh[1] who was a pioneer in the field and accomplished much of lasting value.

[1] Othniel Charles Marsh, American paleontologist, 1831–1899. Professor of Paleontology in Yale University, 1866–1899. Among his important discoveries in American paleontology are his recognition of ancient birds with teeth, the elucidation of the anatomy and relation-

There are extensive collections of dinosaurian remains in the United States National Museum at Washington, in the Yale University Museum at New Haven, and in the American Museum of Natural History at New York City, this last institution containing the most extensive collections of fossil vertebrates brought together in America.

One of the oldest, and certainly the most interesting, case of a deformed joint is the lesion shown in Plates XXIX, b; XXX; XXXI; XXXII and XXXIII. The tumor mass involves two caudal vertebrae of a huge Mesozoic (Comanchean) land reptile, one of the sauropodous dinosaurs (Plate XXVIII), possibly *Apatosaurus*, from the Como Beds of Wyoming. The position of these bones in the body of the animal is indicated by the arrow in the outline reconstruction (Fig. d, Plate XXIX).

The sauropodous dinosaurs were the most gigantic of all land vertebrates, though they were surpassed in size by some of the modern sperm whales. The largest of these reptiles attained a length of nearly seventy feet and an estimated weight of 39 tons. The head was approximately the size of that of a modern draft horse, and the contained brain no larger than one's fist. The lumbar intumesence, however, was ten times the size (Figure 13) of the cephalic portion of the cerebrospinal system, or at least the sub-dural space indicates this to be true. Whether the nervous material filled the entire space is not known. The animals lived, probably, in the swamps and low-lying rivers, feeding on the succulent vegetation. They are said to have been capable of attaining the ripe old age of one thousand years.

Diseases are rarely seen on fossil dinosaur bones, in spite of the abundance of their remains. The tail, in some of the large animals, was long and slender and trailed on the ground (Plate XXIII, c) for a distance of twenty-five feet or more. It may have been used also in swimming, as the musk rat uses its tail today. The terminal caudals, in *Diplodocus* especially, were reduced to slender rods of bone, so that a fracture or other injury was easily possible in this region. Aside from possible blows with the head, the dinosaurs to which these lesions belonged were entirely defenseless. The tail, for example, might have been seized by one of the carnivorous dinosaurs, and vigorously

---

ship of the dinosaurs and his studies on ancient mammals, especially the ancestry of the horse. He contributed 250 studies to vertebrate paleontology, 1862–1899. Some of the larger, more important and elaborately illustrated works are: *Odontornithes: A Monograph of the extinct toothed birds of North America, Washington, 1880, in 4°; Dinocerata: A Monograph of an extinct Order of Gigantic Mammals, Washington, 1896, in 4°; The Dinosaurs of North America, Washington, 1896, in 4°.*

chewed for some time before the owner of the tail had time to turn its huge body and knock the offender away. In this way we may account for the numerous lesions known to occur in the tail of these animals.

The present lesion (Plate XXIX, b) has all the characters of an hemangioma and a detailed description of it is given herewith. The specimen is the property of the Kansas University Museum and I am indebted to Mr. H. T. Martin, the curator of paleontology, for the interesting privilege of studying this fine tumor. A preliminary description of the tumor has already appeared, (Moodie, 1916.3) and all the data are collected here in one place.

The mass resembles closely the tumor-like masses seen on oak trees. It entirely encircles the vertebrae and has involved fully half of each of the two bones. The dark line running vertically in the middle of the specimen indicates the point where the normal union of the two vertebrae would occur, but all evidences of separate structures have been obliterated, and the bones are fused into a single mass.

The specimen has a weight of 5.1 kg., and a length of 26.5 cm. The circumference of the normal articular surface of one of the vertebrae measures 27 cm., and the same measurement around the middle of the mass is 38.5 cm. The lesion has involved a length of 12 cm. Its surface is generally rather deeply pitted and there is an unusual ventral growth carrying with it the 'chevron' (indicated by a star, Plate XXIX, b) a ventral bony element commonly present in these reptiles for the protection of the caudal artery and vein. The growth of the diseased portion is unequal and has involved more of the vertebrae on one side than on the other; likewise, the growth has attained greater lateral dimensions on one side.

The lesion is suggestive of chronic osteomyelitis. It may be a callous growth, due possibly to an intervertebral fracture of the tail; or it may be a bone tumor, and the presence of numerous vascular spaces and channels indicates an hemangioma.

Sawn sections through the middle of the tumor (Plate XXX) show the presence of numerous vascular spaces, which are especially large and numerous near the ventral extremity of the bone. The largest space, to the left in the figure, (Plate XXX) may be a portion of the old intervertebral space which has become incorporated in the pathological mass. The growth of the trabeculae has been unequal and irregular and indicates the pathological nature of the mass.

Microscopic study of the periphery (Plate XXXII) shows the presence of numerous well-developed Haversian systems of osseous

lamellae, usually around a vascular space. The section, (Plate XXXI) magnified 300 diameters, is nicely stained by the infiltration of iron and the osseous lacunae and their short canaliculi stand out with surprising sharpness. On one side of the figure are a number of post-fossilization fractures, due possibly to the action of the frost, or the growth of the contained crystals, and have no significance in the interpretation of the section.

An examination of a thin section taken from the center of the mass shows little structural distinction from that seen in the periphery. The same highly vascular nature of the tissue still obtains, indicating that the entire tumor-mass was well filled with blood. The trabeculae and lamellae are approximately the same in nature and the lacunae are not numerous.

Lesions of a similar nature and doubtless due to a similar cause are known to occur (Plate XXIII, c) in the tails of *Diplodocus* and *Cetiosaurus leedsi*, an English dinosaur. Since these two lesions represent different stages of growth than the one described above, the three lesions give an interesting picture of the stages of growth of an Hemangioma eighteen or more million years ago.

Holland's discussion of these lesions and a reproduction of the figures by him (Plate XXIII, c) and by Hatcher (Plate X, a) will give an adequate conception of the nature of this pathology.

> That the enormously, and at its extremity highly attenuated tail of these great reptiles was liable to injury, is shown by the caudal vertebrae of the Carnegie Museum (at Pittsburg) as well as the caudal vertebrae of *Cetiosaurus leedsi*, preserved in the British Museum. In specimen No. 84 (Carnegie Museum) caudals 2 and 3 are co-ossified as has already been pointed out by Mr. Hatcher in his memoir, and this co-ossification appears to be pathological rather than normal. In specimen No. 94 caudals 20 and 21 are firmly co-ossified, as are also caudals No. 24 and 25. The co-ossification in the case of both of these instances is evidently due to traumatic causes. An examination of the photograph of the rod-like caudals of *Cetiosaurus leedsi* shows plainly that several of these bones have sustained injury, as might easily happen by being crushed under the feet of other individuals, or when used possibly for purposes of defense in giving blows to the right and to the left.

No microscopic examination of any of these lesions has been attempted since there is no reason to think that they differ histologically from the large tumor described above.

SPONDYLITIS DEFORMANS IN THE DINOSAURS

Coalesced vertebrae have been frequently seen, described and figured, in the skeletons of the huge land reptiles of the Mesozoic, and Osborn especially has referred to these pathological lesions as being

the *resting-point* of the tail. This means, I assume, that these gigantic reptiles stood erect and supported themselves with the tail, like the kangaroos. The difficulty with this interpretation is that the coalesced vertebrae often occur elsewhere in the skeleton than at the proper point of the tail. Coalesced cervicals are known in *Camarasaurus*, *Diplodocus*, and *Tyrannosaurus*, and doubtless close scrutiny would reveal the lesions elsewhere in the body.

This condition was extremely puzzling until a series of five caudals (Fig. 15) of *Diplodocus* were studied in the American Museum of Natural History. A fortunate post-fossilization fracture revealed the unaffected articular surfaces of the vertebrae in two places and showed the ring-like growth of the lesion, similar in all respects to the modern advanced cases of *Spondylitis deformans*, so commonly seen in man and mammals. Ruffer has reported a case of this form of pathology in a Miocene crocodile of Egypt, so that the disease is known to occur in other reptiles. The antiquity of the lesion is greatly extended by this occurrence. It is probable that further study will carry the antiquity of this interesting form of pathology far back into geological time.

A badly infected lesion, showing on the surface several large necrotic sinuses, indicates an injury (Plate XXIX, a) to the tail of a large dinosaur, *Apatosaurus louisae*, in the Carnegie Museum. It may be an example of spondylitis deformans, though other lesions of this nature seen in the tails of dinosaurs do not possess necrotic sinuses. It may be an osteomyelitis (Plate XXIX) or an incipient hemangioma. A *Diplodocus* skeleton in the same museum exhibits two lesions on the tail, around which have developed a pathology similar to spondylitis deformans. The injuries in both dinosaurs are near the point where the tail reaches the ground, and it may well be that trauma is the cause of them all.

THE FOSSILIZATION OF BLOOD CORPUSCLES

The study of the pathologic lesions of dinosaur bones has resulted in a number of interesting observations which are on the borderline of pathology and because of their interest those observations[2] will be recorded here. They are concerned with a fundamental question and the phenomenon are so closely allied to pathology as to warrant their incorporation.

[2] Roy L. Moodie, 1920. Concerning the fossilization of blood corpuscles. Amer. Naturalist, liv, 460–464, 1 fig.

Recently, while studying a series of microscopic preparations of fossil material in connection with paleopathology, I observed in sections of a dinosaur bone (possibly *Apatosaurus*) which I had collected in the Como beds of Wyoming in 1906, some ovoid bodies, arranged around the periphery of vascular spaces and Haversian canals, which looked remarkably like blood corpuscles. Close scrutiny of the available material, however, did not satisfy me that the objects might not be the products or by-products of incomplete crystallization. The majority of the bodies have the size and shape of modern reptilian erythrocytes; the nucleus of course not being evident, since only the outward form of the corpuscle was to be seen. Other bodies, apparently similar in nature, were irregular in shape and hard to distinguish structurally from the more regularly formed bodies. The latter, however, may be masses composed of several corpuscles which had become agglutinated.

Not being satisfied with the results of my observations, I should not have published anything in regard to these strange bodies had I not seen in a memoir by Seitz[3] a description of similar bodies in sections of normal bone from a European dinosaur, *Iguanodon Bernissaertensis*, from the Wealden of Bernissaert, Belgium. Seitz's description of the blood corpuscles follows:

> A larger part of the Haversian canals of *Iguanodon* is empty. A part of them, however, contain small, round, biconvex bodies, apparently with flat surfaces, which occur regularly or scattered about in the lumen of the vessels, with an occasional one near the periphery. Not seldom a compact mass of them entirely fills the blood-vessel. Professor Solereder of Erlangen declares that the bodies are not of plant origin (spores) and by polarization it is determined that the bodies resemble somewhat crystalline concretions, so that we are forced to the conclusion that we have here some fossilized blood corpuscles. The partial filling of the blood vessel may be due to coagulation or a peripheral thrombus. There is also to be found frequent accumulations of reddish crystals which resemble hematoid crystals, and which support the suggestion as to the nature of the material. I give these observations with some reservation.

We may gain an insight into the possiblity of the fossilization of blood corpuscles by studying the results of the researches into the nature of the mummified brain material of the ancient Egyptians. This subject has been studied by Mair,[4] who finds that the lipoids of the brain from Coptic bodies, 500 B. C., had been changed into cholesteryl

[3] The lengthy title of this fine memoir is given in footnote 2 of Chapter IV.

[4] W. Mair, 1913. On the lipoids of ancient Egyptian brains. J. Path. and Bacteriol., xviii, 179–184; 188.

stearate and palmitate.[5] Mair obtained cholesteryl stearate by heating cholesterol with stearic acid, and one may infer that the heat of the desert sands in which the bodies were buried may have been an important factor in the conversion of brain lipoids into the two relatively resistant substances, palmitate and cholesteryl stearate. These brains, even those dating from a period prior to the process of embalming (4500 B. C.), are frequently so well preserved though greatly shrunken, that practically all the gyri may be accurately determined. This item from more recent times may aid in an explanation of processes occurring in geological ages.

The studies on Egyptian mummies have not resulted in the discovery of blood corpuscles, even Ruffer's extensive histological observations on mummified tissues did not yield any positive results. Schmidt[6] examined bodies dating from 1000 years before Menes (3400 B. C.) to 500 B. C. (mummified material from Coptic bodies) and was unable to find a positive haemin reaction, tending to show the complete disappearance of all blood in the process of time. Wood Jones,[7] however, is convinced that traces of blood are readily discernible. Elliot Smith has referred to blood stains on bandages used in the primitive surgery of Egypt.

It may be of interest to note that Friedenthal[8] announced to the physiological society of Berlin the discovery of red blood in the body of a mammoth from eastern Siberia which had been frozen in the tundra since Pleistocene times. The precipitin reaction of the blood is similar to that of the modern elephant. No record is made of the preservation of blood corpuscles. While this is an extremely interesting discovery, it must be recalled that cold brings many chemical reactions to a halt, and there may have been little change in the blood of this mammoth during its 175,000 years of cold storage in the Siberian mud. The body had been so well frozen that the flesh was eaten by wolves and dogs.

Hoppe-Seyler has shown that dried red blood corpuscles of man contain 2.5 parts of cholesterin in 1000. While this is an extremely

[5] Mair's results are confirmed and extended by Lapworth and Royle, 1914, The lipoids of ancient Egyptian brains and the nature of cholesteryl esters. J. Path and Bacteriol., xix, 474–477.

[6] W. A. Schmidt, 1907. Chemische und biologische Untersuchungen von ägyptischen Mumienmaterial, nebst Betrachtungen über das Einbalsamierungsverfahren der alten Aegypter. Ztschr. f. allgemein. Physiol., vii, 369–392.

[7] F. Wood Jones, 1908. The post-mortem staining of bone produced by the ante-mortem shedding of blood. Brit. Med. J., i, 734–736.

[8] Deutsche Med. Wochenschrift, 1904, p. 901.

small amount of lipoid substance, since it is chiefly in the cortex of the corpuscle, it occurred to me that this might offer an explanation of the preservation of blood corpuscles. That is, under favorable conditions, the lipoids of the blood might be changed into some resistant substance like palmitate or cholesteryl stearate and thus retain the form of the corpuscle and delay their destruction long enough for fossilization to set in; these substances being replaced later by the mineral crystals from the magma in which the body was immersed. The beautiful little ganoid fish brains described[9] some years ago from the Coal Measures may have been preserved in a similar way, though microscopic study[10] of the brain does not help us to reach a definite conclusion one way or the other. The resemblance between brain substance and blood corpuscles is close in this respect that each has a small amount of resistance substance, a large amount of water and a relatively similar proportion of lipoids which may have been transformed, under proper conditions, into resistant substances which carried the part over the critical period of destruction.

In view of the fact that so many soft-bodied animals are so beautifully preserved[11] in the rocks, that the histological nature of Paleozoic muscle tissue has been determined, that bacteria and the delicate parts of animals are so frequently fossilized, it is certainly not beyond reason to expect the preservation of blood corpuscles. The subject is still an open one but this contribution to the theory of fossilization, it is hoped, may help to clear up the matter of the preservation of delicate parts.

The fossilization of any of the blood crystals, as suggested by Seitz, is extremely improbable, since the evanescent nature of blood crystals is well known. Whether the crystals seen with the supposed blood corpuscles have resulted secondarily from the disintegration of haemin crystals or whether the entire appearance is due to chemical reactions in the incomplete crystallization of inorganic substances is an open question.

The so-called corpuscles seen by me line the vascular spaces in a normal metatarsal of *Apatosaurus*, or some related dinosaur, from

[9] Roy L. Moodie, 1915. A new fish brain from the Coal Measures of Kansas, with a review of other fossil brains. J. Comp. Neurol., xxv, No. 2, 135, 17 figs.

[10] Roy L. Moodie, 1920. Microscopic examination of a fossil fish brain. J. Comp. Neurol., xxxii, No. 3, 329, 2 figs.

[11] The most remarkable discoveries are those of C. D. Walcott, discussed in various technical papers and popularly reviewed by him with references to the literature in: Evidences of Primitive Life. Smithsonian Report for 1915, pp. 235–255, with many beautiful figures.

the Como beds of Wyoming. They appear as rounded bodies which at a magnification of 200 diameters measure 6 mm. They are undoubtedly the same bodies seen by Seitz in a European dinosaur. The vascular space, filled with quartz crystals, contains many of the rounded bodies. The osseous trabeculae stand out in sharp contrast by reason of their dark iron content. Along the margins of the vascular space are also seen sharp indentations which may be interpreted as Howship's lacunae, in which case the rounded bodies may be osteoclasts instead of blood cells. Renault failed to find blood cells in ancient bone.

ARTHRITIDES IN THE MOSASAURS

Our knowledge of the mosasaurs is due in great part to the active studies of Williston,[12] who noted evidences of disease among the ancient vertebrates of the Cretaceous and Permian of North America. Representative specimens of mosasaurs from the Cretaceous of Kansas are to be seen in all the large museums of the world, and thousands more await the future explorer.

One of the most interesting examples of deforming arthritides is that exhibiting an osteoma (Plates XLVIII, c-d; XXXIX; XL) and surrounding lesions at the interarticular surface of the third and fourth dorsal vertebrae of a mosasaur, *Platecarpus coryphaeus*, from the Niobrara Cretaceous of Kansas. I am indebted to Dr. John M. Armstrong, of St. Paul, Minnesota, for the gift of this unique specimen. He secured it from Mr. Charles Sternberg, the veteran collector of fossil vertebrates.

The mosasaurs (Fig. 16) were rather large aquatic reptiles, some of

[12] Samuel Wendell Williston, American Paleontologist, 1852–1918. He received his training in paleontology under Professor O. C. Marsh at Yale University, under whom he worked from 1876–1885. From 1890–1902 Williston assembled at Kansas University one of the most notable collections of Cretaceous vertebrates ever made. His discussion on the nature of the Kansas Cretaceous vertebrates resulted in many studies and special monographs, such as: *Mosasaurs (1898)*, *Turtles (1898)*, *Plesiosaurs (1903)*, *Pterodactyls and Nyctosaurus (1903)*. From 1902–1918, as Professor of Paleontology in the University of Chicago he studied the vertebrate fauna of the Permian Red Beds of Texas, and made a splendid collection of forms from this horizon. His studies, issued mainly in the *Journal of Geology* and by the University of Chicago Press, are noteworthy achievements in the annals of American Paleontology. *Cacops and Desmospondylus (1910); American Permian Vertebrates (1911); Water Reptiles of the Past and Present (1914)* are monographic studies on the reptiles of the Permian of America. Aside from his interest in fossil reptiles Williston attained great recognition as an authority on the taxonomy of the Diptera, his *Manual of the Diptera of North America*, New Haven, 1908 being recognized as an authoritative study of the classification of the dipterous insects of America. An active worker in many lines of science Williston, as a student of medicine, recognized the significance of the diseases of ancient animals and commented upon it.

them attaining a length of fifty feet. They had a world-wide distribution and produced a variety of species but existed only during the later part of the Cretaceous. Perhaps nowhere in the world are the fossil remains of marine reptiles more abundant than in the famous chalk beds of Kansas (Fig. 17). Long continued explorations by collectors have brought to light thousands of specimens of these swimming lizards, some of them of extraordinary completeness and perfect preservation. The complete structure and relations of all parts of the skeleton and some of the soft parts, and the skin are known and now we are to learn something of the nature of the diseases from which these animals suffered. An interesting case of osteoperiostitis and various necroses are described herewith.

The osteoma, for such it may readily be called, does not involve a great deal of the intervertebral surface but has overlapped the junction of the two vertebrae (Plate XXXIX) and by adhesion has formed a weak ankylosis. The greater part of the osteoma, however, lies on the posterior end of the third vertebra, on the right side, while on the left there is an extensive overgrowth of the vertebral junction.

The lesion, as determined in a sawn section (Plate XL) attained a thickness of 10 mm. and a length of 25 mm. On the right of the bone the lesion is relatively smooth with lines of growth running circularly around the body of the mass, interrupted anteriorly by an invading mass of rougher bone. The portion on the left side is quite roughened and raised into a series of irregular ridges. The osteoma is sharply marked off from the body of the vertebra itself and has involved only a portion of the vertebral tissue (Plate XL). The lesion seems to be a real exostosis and not a mere osteophyte.[13]

Its growth from the body of the vertebra may be seen in the figure (Plate XL). An examination of the sawn section shows that the osteoma began as a pathological condition near the end of the vertebra and grew anteriorly along the ventral surface of the body of the vertebra, leaving a sharp and clean cut distinction between the osteoma and the vertebra itself. The vascular spaces in the osteoma are arranged at right angles to those of the vertebra and the trabeculae of bone in the osteoma are much more contorted and convoluted.

[13] The following definitions of these two terms given by L. Hektoen: An American Textbook of Pathology, 1901, p. 672, may help in forming a decision:

Osteophyte: Circumscribed nodular or flat periosteal inflammatory bone formations are called osteophytes.

Exostoses are circumscribed external new formations of bone that in their genesis correspond more closely to true tumors.

Microscopic examination (Plate XXXIX, b and d) of a section taken from the junction of the osteoma and vertebra reveals a great amount of disturbance in the structure of the bone, a reduction in vascularity and a rearrangement of the trabeculae. The growth is a true tumor formation, involving the substance of the vertebra.

OSTEOMATA AMONG MODERN VERTEBRATES

Bony tumors are known to occur commonly among modern vertebrates and it is surprising that more is not known of fossil representatives of this type of tumor. J. Bland Sutton[14] has reviewed in part the literature dealing with this class of objects and mentions osteomata of the frontal sinuses occasionally seen in oxen, where they often form huge irregular lobulated masses, sometimes weighing as much as sixteen pounds, and as dense as ivory. Paul Gervais[15] has published descriptions of many interesting tumors from fishes, and Sutton figures a specimen of *Chaetodon* furnished with many rounded bony tumors.

A similar type of tumor may be expected in paleontological collections, the odontomata, which have been described as occurring in the horse, the dasyure, the goat, marmot, elephant, Canadian porcupine, and other rodents. No objects similar to these are known in a fossil condition.

MULTIPLE ARTHRITIS IN A MOSASAUR

That the ancient swimming reptiles often suffered rheumatic pains is indicated by the occurrence of arthritic lesions in a nearly complete series of foot bones representing the left hallux of a large mosasaur, *Platecarpus*, the complete skeleton of which is in the Kansas University museum. I am indebted to Mr. H. T. Martin for loaning these interesting specimens for study. The metatarsal (Fig. a, Plate XLI) is especially pathologic, flattened, shortened, necrotic, and covered with carious roughening. When compared to a normal metatarsal the pathology is very evident. Each successive joint of the toe is deformed, enlarged, necrotic, with the articular ends of the phalanges lipped, similar to the lipping observed in arthritis in human skeletons. This is the first known example of multiple arthritis in a fossil vertebrate. The primary lesion was doubtless at the metacarpotarsal junction, from which point it spread by metastasis to the other joints.

[14] Tumors—Innocent and Malignant, Their Clinical Features and Appropriate Treatment, Philadelphia, 1893, 8°, Chap. III.

[15] Jour. de Zoologie, 1875, vol. iv.

Microscopic study of the joint surfaces shows an increased vascularity of the tissue, differing from the normal bone of the shafts where the tissue is more dense. The hypertrophy observed in the ends of the bones is doubtless due to the increased vascularity. The nature of the finer elements of bone remain unchanged.

CRETACEOUS OSTEOPERIOSTITIS WITH ARTHRITIC LESIONS

The pathological arm bones (Plate XXXIV) of a Cretaceous mosasaur must be considered here, not because the lesions are all of an arthritic nature but because the surface lesions have run over into the joint cavity and what originally was doubtless a case of surface osteoperiostitis has resulted in an extensive deforming arthritic condition.

Osteoperiostitis or some similar sub-periosteal inflammation is evidently the cause of various flattened lesions which occur abundantly on the humerus and radius of a mosasaur, described by Williston (1898), in association with a portion of the carpus and a metacarpal bone. All of these osseous elements are covered with exostosial lesions, excepting that at the distal end of the humerus the lesions have grown over the joint cavity and the articular surfaces of the bones are only slightly affected. The joint surfaces of the bones of these animals are always roughened, apparently for the attachment of the articular cartilage, and it is difficult to determine the amount of disease which is present.

The lesions on the surface of the humerus (Plate XXXIV) are flattened, irregular, and fairly extensive over the distal two-thirds of both sides of the bone. Their appearance is quite different from the normal surface of the bone, being much more eburnated and dense. The largest single lesion occupies an area of 35 mm. by 50 mm. The surfaces of all the lesions are irregularly pitted, as if penetrated by nutrient vessels. Nutrient foramina are very abundant on the surface of all mosasaur limb bones, and it is probable that the lesions were formed around the nutrient arteries. None of the lesions attains a thickness of more than 4 mm.

The line of union, as seen in a sawn section (Plate XXXV, d) between the diaphysis and the lesion is a sharp one, and in the fossilized bone the lesion has a darker color than the normal bone. The osseous trabeculae of the lesion are more vascular than those of normal bone. The intertrabecular spaces are small, fairly regular with no large openings, the small spaces in the fossil being filled with calcite crystals.

Microscopic examination of a thin section, 12 micra, shows the nature of the histological details of the lesion very well. Two important

facts are very striking: the preservation of true osteoid tissue and abundant perforating fibers of Sharpey. The section (Plate XXXVI) is filled with vascular spaces, occupied by calcite crystals. An especially large one seen in the right portion of the figure may be an Haversian system.

The perforating fibers of Sharpey are made up of thread-like strands (Plate XXXVII) which run, apparently, through the lamellae of bone, as in modern times. A high power study shows the canaliculi short and unbranching and they are not interfered with by the bundles of perforating fibers of Sharpey.

The osteoid tissue (Plate XXXVII) characterized by the absence of canaliculi, occupies the peripheral portion of the section. In general appearances there is no difference between the osteoid tissue seen in this ancient lesion and that seen in a recent human humerus in a case of osteomyelitis.

HISTORY OF SPONDYLITIS DEFORMANS

The following brief tabular survey of *Spondylitis deformans* will show for one form of pathology the antiquity and nearly continuous history of one diseased condition, widely prevalent at the present time. The age given is in terms of the maximum years allotted the geological periods to which must be added an enormous undetermined period of time for the Epi-Mesozoic interval. The history begins with the Comanchean though doubtless closer scrutiny of the Permian vertebrates would also reveal it there.

	Estimated age in years.
Comanchean-evidences seen in various dinosaurs	110,000,000
Cretaceous-evidences seen in various dinosaurs	86,000,000
Eocene-evidences seen in primitive ungulates	50,000,000
Miocene-evidence seen in an Egyptian crocodile	15,000,000
Pliocene-evidence seen in lumbar vertebrae of a camel	1,800,000
Pleistocene-evidences seen in cave-bears,[16] saber-tooth cat	750,000
Neolithic man	75,000
Ancient Egyptians	6,000
Pre-Columbian Indians of America	600

On the basis of the maximum estimate it has been since life existed in such form as to leave recognizable fossils nearly 600,000,000 years, and the pathology of Spondylitis deformans has had its present characteristics for about one-sixth of that time. This is but a small part of

[16] M. Baudouin, 1912. Les maladies des animaux préhistoriques. La spondylité déformante chez l'ours des cavernes (Ursus spelaeus). Comptes Rendus Acad. des Sci., Paris, p. 1822.

geologic history since the study of radioactive substances suggests a duration of 1,600,000,000 for the Archeozoic alone.

SPONDYLITIS DEFORMANS IN EOCENE MAMMALS

Definite evidences of this arthritic disturbance are observed in two Eocene mammals. *Limnocyon* (No. 13139, American Museum of Natural History) shows spondylitis in two caudal vertebrae in which the lateral ligament of the tail is involved. The lesions, old as they are, are extremely like similar lesions in human vertebrae. Another example is that of *Pantolambda* (No. 16663, American Museum of Natural History) which shows spondylitis in the ventral ligament of the anterior dorsals or posterior cervicals. This animal is derived from the Torrejon, Paleocene beds. No evidences of the incipient lipping were definitely observed, though it was suggested in a number of places on the vertebrae. The conclusion derived from the observations are that the condition was not one of long standing but in its early stages. It must take many years to produce the firm ankylosis seen in the advanced cases of spondylitis deformans.

SPONDYLITIS DEFORMANS IN A MIOCENE CROCODILE

The typical lesions of chronic joint disease, belonging to the phase under discussion, have been reported by Ruffer (1917) in a Lower Miocene crocodile, *Tomistoma Dowsoni*, from Egypt. He has also given in this paper a splendid comparative review of the literature giving instances of this phase of pathology, as well as describing (1918.2) fully the nature of this disturbance among ancient Egyptians. At the time when Ruffer wrote (1917) spondylitis deformans had no known antiquity of great duration. It had been observed in the skeleton of a man from the Quaternary station of Raymonden, a village situated in the commune of Chancelade, seven kilometers to the northeast of Péribueux; in prehistoric skeletons described by J. de Baron; in remains from the Neolithic ossarium of Bazoges en Pareds; in the historic remains from Caithness, England; in the cave-bear; in an extinct bison; in the sacred monkeys of Thebes; in the sheep and oxen of ancient Egypt and traces of ossific inflammation in the pelvis of *Bos africanus*. None of these examples, however are older than the Pleistocene. We now know spondylitis deformans as old as the Comanchean period.

The specimen representing the fossil crocodile was discovered by M. Fourtau, of the Geological Museum, Cairo, near Hateyet el Mog-

harah, a lake in the Mariut desert and consists of two vertebrae thoroughly petrified. A thick band of osseous tissue, obviously pathological, firmly binds the vertebrae together. On the right side the pathological osseous band extends to the base of the transverse process of the posterior vertebra. A distinct pathological osseous arch with its concavity towards the intervertebral space bridges over an opening which may have borne a bloodvessel. The new bone is sharply separated from the bodies of the vertebrae, superadded to them, and is thickest on one side. In the crocodile, as in man, the disease is more marked on one side.

SPONDYLITIS DEFORMANS IN A PLIOCENE CAMEL

The history of this interesting form of pathology, already shown to be very extensively developed among fossil vertebrates, is made more complete by a specimen loaned me for study by Mr. Harold Cook of Agate, Nebraska. It consists of two firmly ankylosed lumbar vertebrae (Fig. a, Plate LVIII) of a very large undetermined camel from the Snake Creek, Pliocene, beds of northwestern Nebraska.

These deposits are extremely interesting and are productive of a rather extensive mammalian fauna. The bones are usually found on sparsely grass-grown hill-tops, loose in sand, greatly intermingled, and largely water worn, but very thoroughly petrified. There are pockets which contain hundreds of bones, teeth, and fragments with an occasional complete or approximately complete skeletal part, such as the lower jaw of the rhinoceros (Figure 24) which bears the evidence of Pliocene actinomycosis. Rarely are skeletal parts associated, indicating the distributing action of water or the erosive power of wind-blown sand.

The camel vertebrae form no exception to the majority of fossils from this locality. The specimen is greatly eroded, but presents all the evidences of typical spondylitis deformans, with the lipping projecting over the free edges of the articular surfaces in two blunt exostoses. The articular surfaces between the two vertebrae are hidden by a flat encircling band of bone which forms a firm union of the two bones.

It is interesting to place in a series a modern human lumbar vertebra, the vertebra of a saber-tooth tiger from the Pleistocene of California, a lumbar from a European cave bear and the Pliocene camel, all bearing lesions of this same pathology, and note the very close similarity of form the lesions have adopted at different ages in the earth's history.

Ruffer (1921) has described and figured a lower Miocene crocodile from Egypt showing evidences of this pathology and I (1920.3) have discussed its occurrence in the Eocene, and Cretaceous and Comanchean. So that the record is unusually complete for this form of pathology. Ruffer has given (1921) the best discussion to date of the nature and occurrence of this pathology among ancient human races. He has also given a discussion as to the causes of this disease but from the facts at hand no reliable conclusion can be drawn as to its etiology.

It will be interesting to give here the detailed measurements of the camel lumbar vertebrae, with especial attention to the pathological lesions, thus giving a more accurate insight into the extent of the exostoses.

Length of normal bones above exostoses	84 mm.
Length of entire specimen including exostoses	95 mm.
Width of articular surface of vertebra	32 mm.
Length of exostosis	8 mm.
Width of largest exostosis	22 mm.
Estimated thickness of encircling band	5 mm.

SPONDYLITIS DEFORMANS AMONG PLEISTOCENE MAMMALS

Pathological lesions of the lips of the vertebrae of varying extent have been known on Pleistocene fossils for a long time. They were among the earliest lesions seen on cave-bears and have been discussed by von Walther (1825), Mayer (1854), Virchow, Schlosser, Abel and many other writers on pathological conditions among ancient vertebrates. Ruffer (1917) in his paper on the pathological vertebrae of a Miocene crocodile has given the best literature review so far. In this review he discussed evidences of articular osteitis in early man and ancient animals, giving all literary references needed.

A comparison of various Pleistocene and recent lesions is shown in Plate XLIII, and an idea of the histological changes involved may be had from an examination of the photomicrograph (Plate XLII). There are undoubtedly many evidences of this form of disease among the numerous Pleistocene vertebrates of the Rancho la Brea, and the promised monographic studies of this fauna will doubtless contain much that is new to this disease. The only example I have had at my disposal is that of a lumbar vertebra of *Smilodon*, a large saber-tooth cat or tiger given me by Mr. E. S. Riggs (Plate XLIII). Judging from the nature of the lesion there were several vertebrae firmly united into a solid mass, recalling conditions seen in ancient Egyptians as described by Ruffer (1921). Ruffer has also discussed the causes underlying the

ception and progress of this disease. His conclusions leave one very ıcertain as to its etiology in human beings, so we are much more unrtain about it among fossil forms. Certainly all factors such as vellings, food, alcohols, and drugs may be eliminated from the nosaurs and other fossil reptiles, so the best we can say as to its origin : "We do not know!"

DESCRIPTIONS OF FIGURES 11-18 AND PLATES XXVII-XLIII ILLUSTRATING CHAPTER V

FIGURE 11

Fractured rib, with considerable callus and hypertrophy in a skeleton of the American Mastodon in Yale University.

FIGURE 12

Outline sketch showing normal appearance of the two vertebrae shown in Plate XXIX, b, based on Apatosaurus. A-chevron. This process in the pathological specimen has been shoved far ventralward and is involved in the tumor-like mass.

FIGURE 13

Outline reconstruction of one of the giant dinosaurs, which attained a length of almost seventy feet, showing relative capacity of the dural spaces in the head, spinal canal, sacrum and tail.

Figure 11

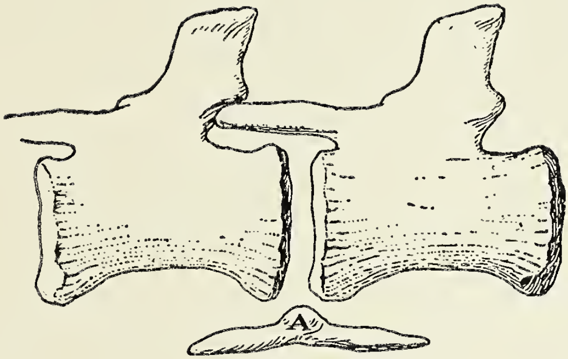


Figure 12

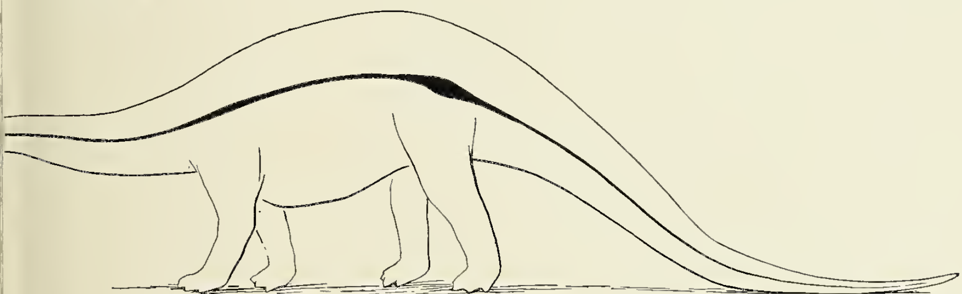


Figure 13

FIGURES 14-15

FIGURE 14

Sawn hemisection through the large dinosaur tumor, showing the arrangement of the osseous trabeculae and vascular spaces.

One-half natural size.

The chevron projects ventrally.

FIGURE 15

Caudal vertebral, Nos. 17–21, of *Diplodocus longus*, seen from the right side, showing coalescence of the vertebral articulations by the lesions of *Spondylitis deformans*. The entire series has a length of about five feet. The opening seen in the first lesion to the left allows an examination of the articular surfaces which are seen to be unaffected by the disease. A fortunate fracture through the second lesion from the left shows the entire articular ends of the vertebrae, unaffected by disease, and the ring-like lesion of spondylitis. The ventral chevrons are broad in this region, for at this point the 30 foot tail of the creature reached the ground. Specimen in the American Museum of Natural History. X 1/15. (After Osborn.)

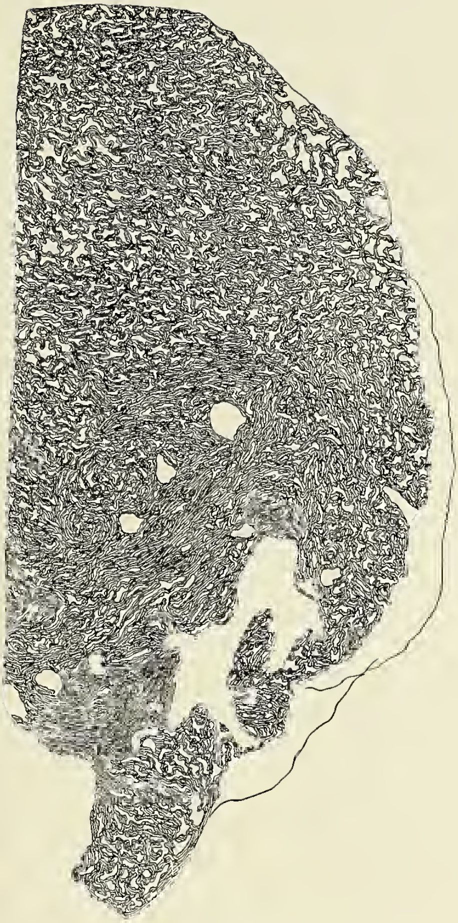


Figure 14

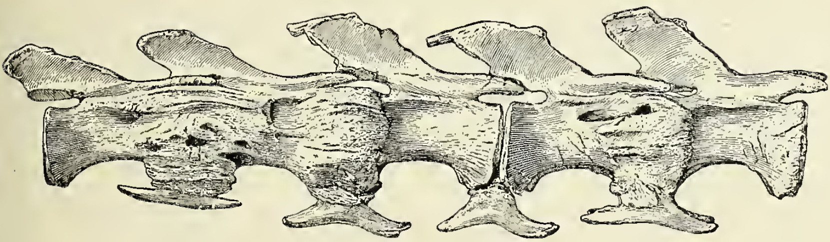


Figure 15

FIGURE 16

FIGURE 16

Restoration of a Kansas Cretaceous Mosasaur, *Clidastes*, shown in association with the floating crinoid, *Uintacrinus socialis*, and the flying reptile, *Pteranodon ingens*. (After Williston.)

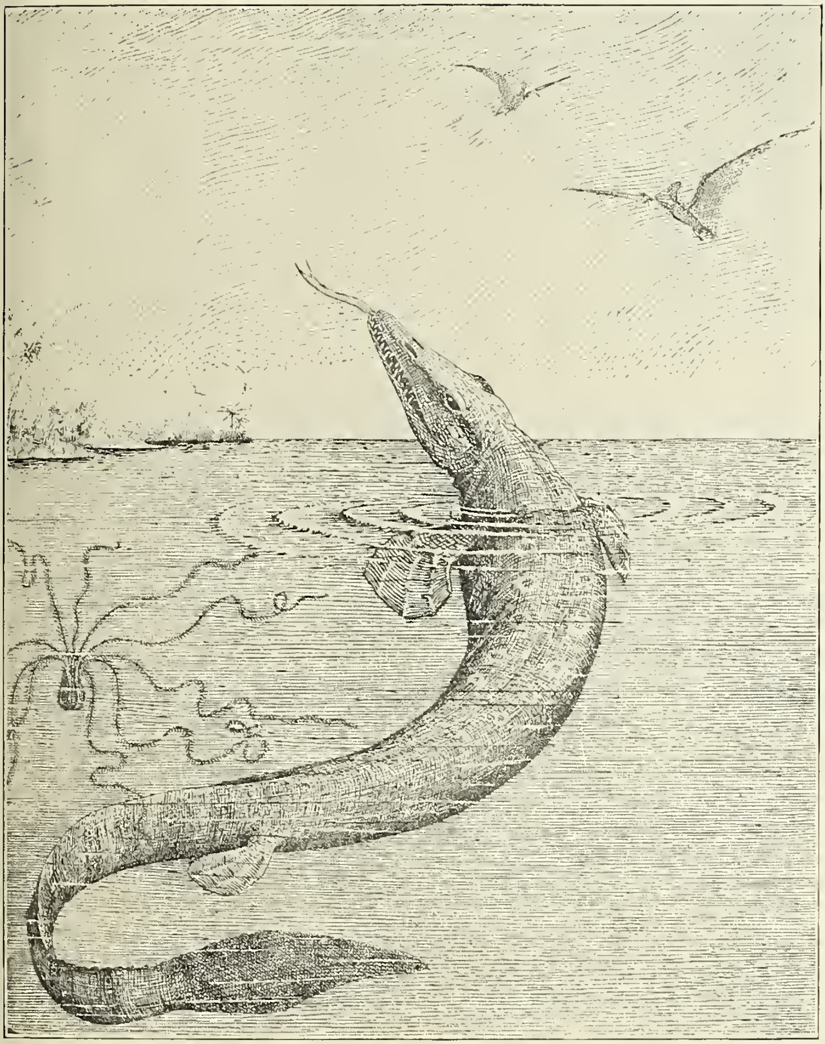


Figure 16

FIGURES 17-18

FIGURE 17

A large exposure of the famous Niobrara Cretaceous chalk deposits of Kansas. At the "X" in the upper center part of the figure a pterodactyl skeleton was found. Fossil mosasaur, plesiosaur, pterodactyl, and fish bones are to be found projecting at intervals throughout the cliff, but complete or fairly complete skeletons are rare. From these or similar cliffs were recovered the pathological bones described herewith. The cliffs may truly be regarded as the 'book of nature' since the succeeding layers of rock have different tales to tell.

FIGURE 18

The form of the normal elements of an arm of a Cretaceous swimming reptile from Kansas. (After Williston.)

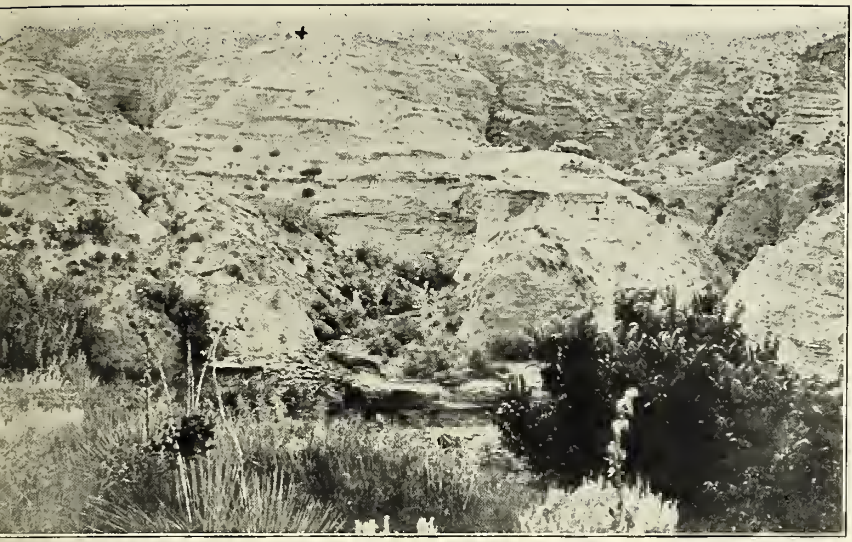


FIGURE 17

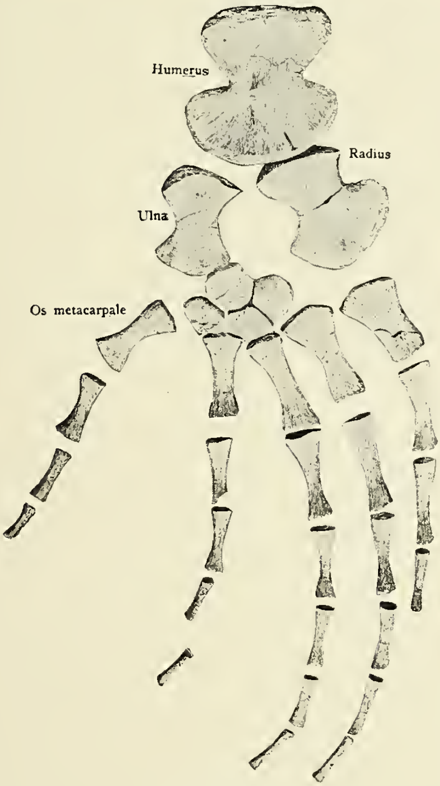


FIGURE 18

PLATE XXVII

PLATE XXVII

DISTINGUISHED PALEONTOLOGISTS

Upper left. Sir Richard Owen, an English anatomist and paleontologist, 1804–1892.

Upper right. Othniel Charles Marsh, an American Paleontologist, 1831–1897.

Lower left. John Bell Hatcher, American paleontologist, 1861–1904.

Lower right. Samuel Wendell Williston, American paleontologist and dipterologist, 1852–1918.

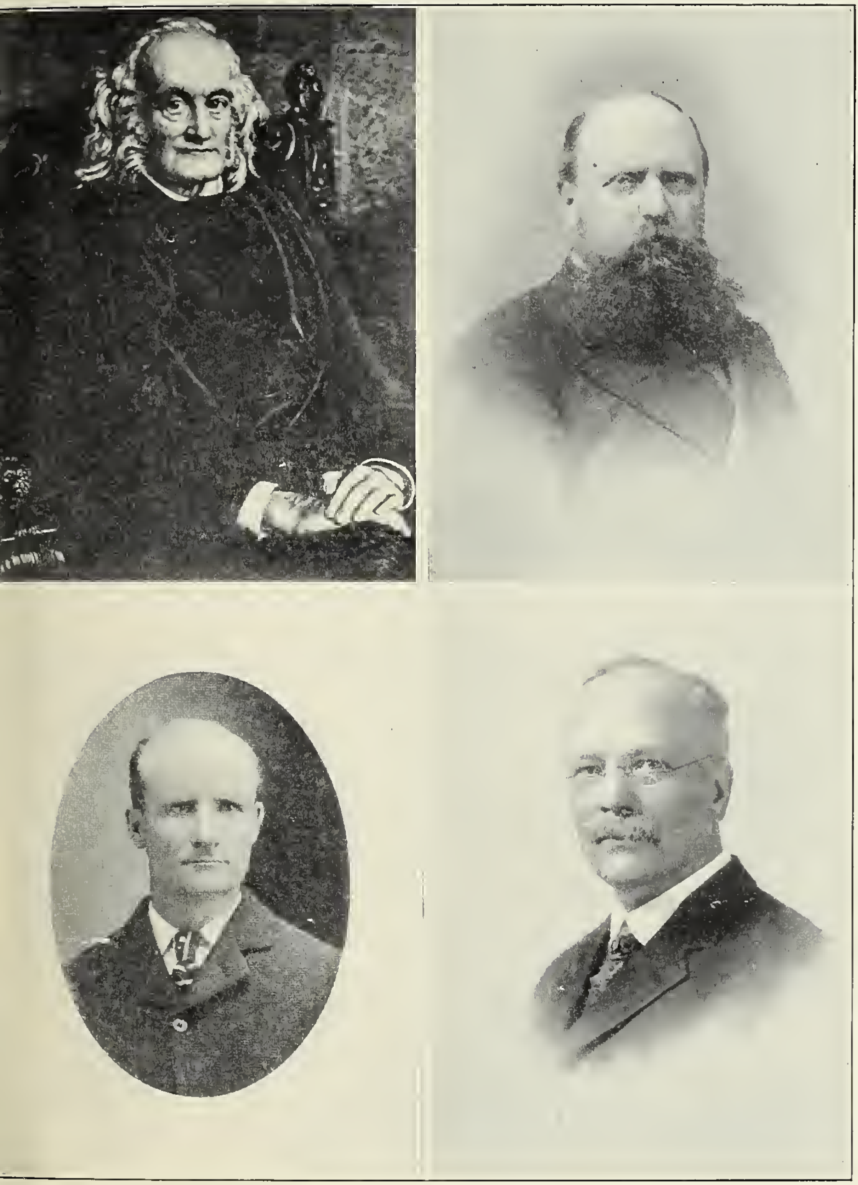


Plate XXVII

PLATE XXVIII

PLATE XXVIII

Upper. Restoration of the giant reptile, *Apatosaurus*, as it may have appeared in its Mesozoic haunts. Note the long slender tail, easily subject to trauma. The tail in *Diplodocus* was even longer and much more slender. After Osborn.

Lower. A dinosaur in the rocks.

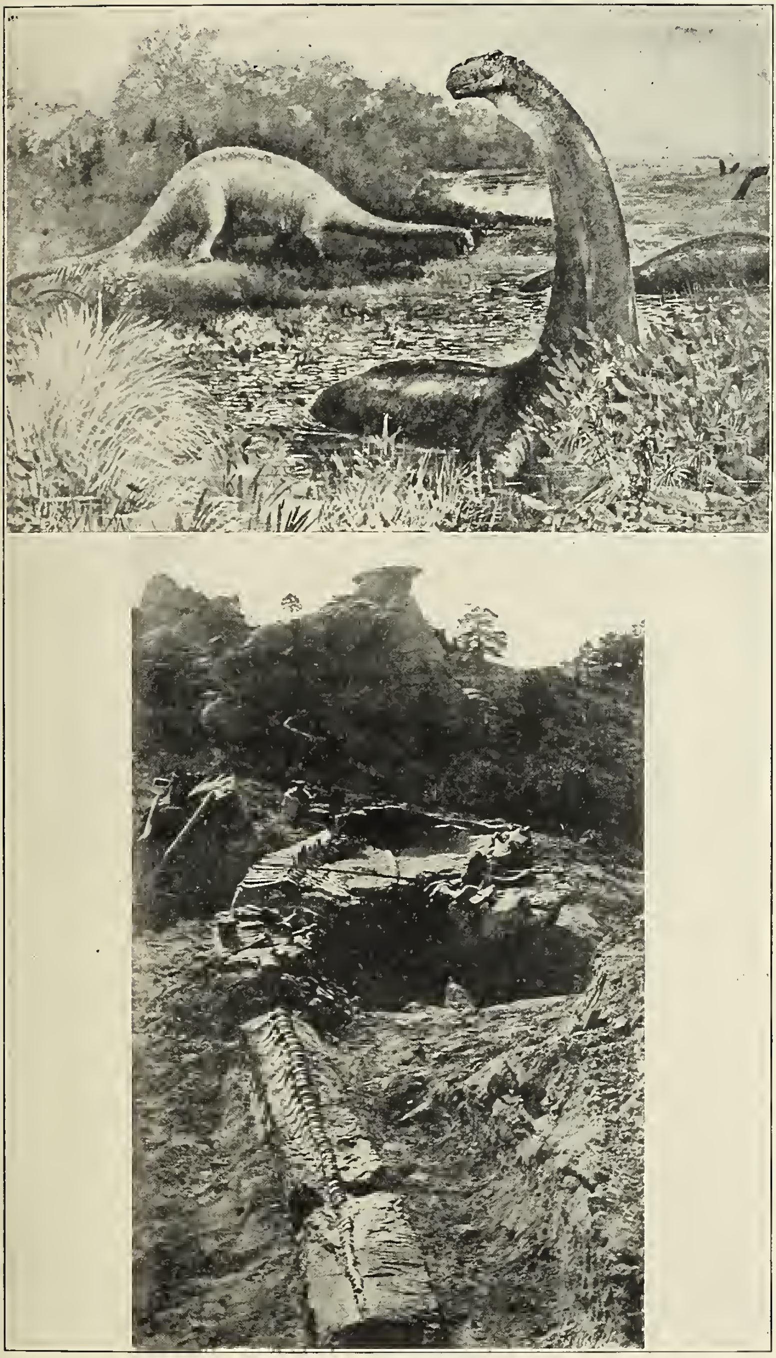


Plate XXVIII

PLATE XXIX

PLATE XXIX

DEFORMING ARTHRITIDES IN THE DINOSAURS

a. Right side of caudals 22 and 23 of the giant dinosaur *Apatosaurus Louisae* Holland, showing lesion due possibly to a fracture of the joint, since the surface shows many necrotic sinuses indicating a long-standing sepsis. There is some little restoration with plaster on this surface, less on the other.

b. Two caudal vertebrae of a sauropodous dinosaur, possibly *Apatosaurus*, exhibiting a pathological lesion which may be interpreted as a haemangioma, a callus, chronic osteomyelitis, or some unknown cause. This is one of the most interesting evidences of disease among fossil animals. The specimen is from the Como Beds (Comanchean) of Wyoming and is the property of the Kansas University Museum.

c. Scapula of a large Dinosaur, *Trachodon annectens*, from the Lance Formation, Niobrara County, Wyoming, showing an anomalous vascular foramen. Skeleton mounted in Yale University Museum.

d. Outline figure, with skeleton of *Apatosaurus*, showing location of pathological vertebrae. This animal attained a length of nearly 70 feet, a height of 14 feet, and a weight of nearly 40 tons. Based on a figure by Matthew.

Plate XXIX

PLATE XXX

PLATE XXX

A FOSSIL HEMANGIOMA

Sawn sections through the middle of the tumor mass of the hemangioma in the caudal vertebrae, shown in Plate XXIX, b.

The upper figure shows, slightly enlarged, the distribution of the osseous trabeculae at the periphery of the tumor. It is to be noted that the vascular spaces increase in dimensions and number as the periphery is approached.

The lower figure exhibits the distribution of vascular spaces at the center of the tumor mass. The very large space at the left may be the remains of the intervertebral space since the section was cut at the junction of the two vertebrae. Other smaller vascular spaces are shown scattered throughout the photographic field.

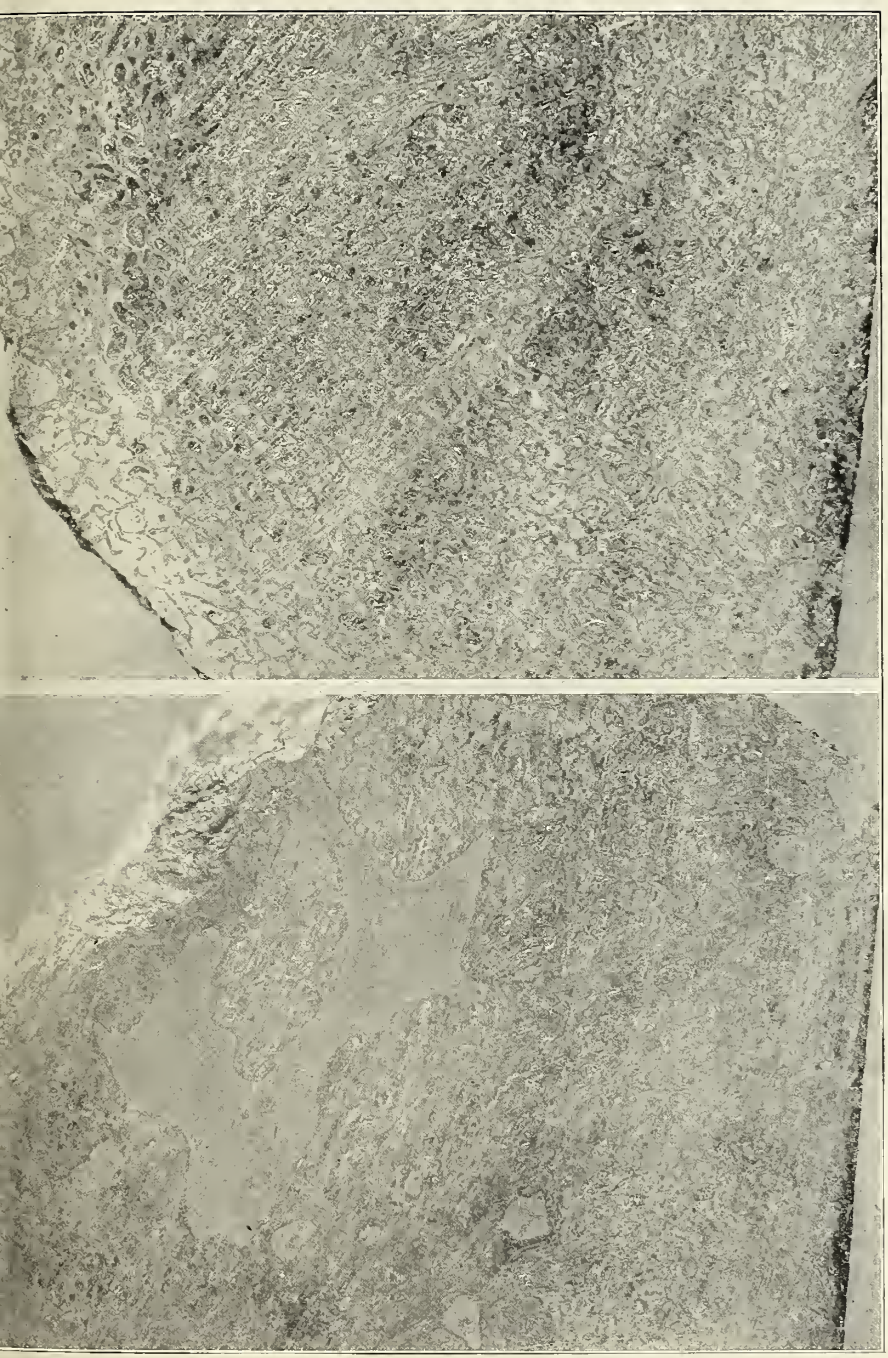


PLATE XXX

PLATE XXXI

PLATE XXXI

Microscopic study of portion of the periphery of the large tumor from the tail of a dinosaur, showing the osseous lacunae, with small canaliculi, arranged around a large vascular opening, thus simulating an Haversian system. The lacunae of the dinosaur bones are much smaller than are the lacunae of other fossil animals. The dark areas are due to the staining of iron with which the bones are infiltrated. X 300.

Plate XXXI

PLATE XXXII

PLATE XXXII

HISTOLOGY OF DINOSAUR BONE

a. Photomicrograph of a portion of an osseous trabecula, showing nature of lacunae and indications of lamellae. The space to the right is a vascular channel. X 300.

b. Photomicrograph of periphery of dinosaurian hemangioma from the Como Beds of Wyoming, to show nature of the lacunae, shown in the black spots. There are two large vascular spaces. X 300.

c. The lacunae in this section of dinosaur bone from the hemangioma show very clearly the absence of canaliculi. X 300.

d. Photomicrograph of another area of pathologic dinosaur bone, showing the nature and arrangement of the bony elements around the large vascular space in the center. X 70.

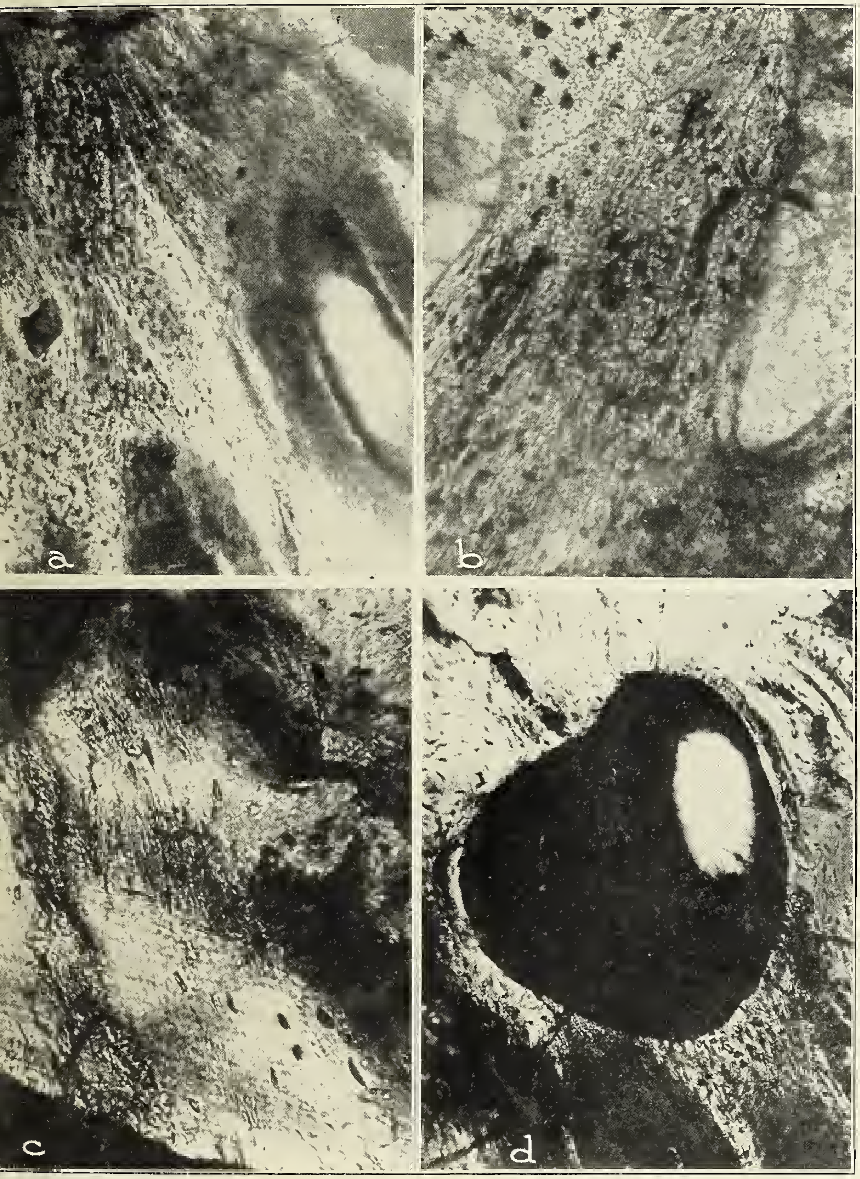


Plate XXXII

PLATE XXXIII

PLATE XXXIII

HISTOLOGY OF FOSSIL HEMANGIOMA

a. Photomicrograph of a section taken from a region of the periphery of the fossil dinosaur bone tumor, showing in an oblique view the distribution of the lamellae, lacunae, vascular spaces and trabeculae of bone. This is all pathologic bone and formed a small exostosis of the periphery of the tumor. X 70.

b. One of the trabeculae, shown in "a," exhibiting the nature of the lamellae, and lacunae with their short canaliculi. An especially well developed lacuna, possibly filled with bacteria, is shown in the lower right hand corner. X 300.

c. One of the adjoining trabeculae showing the nature of the lamellae, and lacunae with short canaliculi. The large dark space in the upper right hand corner is a vascular canal around which the lamellae are arranged in a somewhat concentric manner. X 300.

d. Section taken from the periphery of the fossil dinosaur bone tumor showing in an oblique view the distribution of the lacunae, vascular spaces, and trabeculae of bone. This is all pathologic bone. X 70.

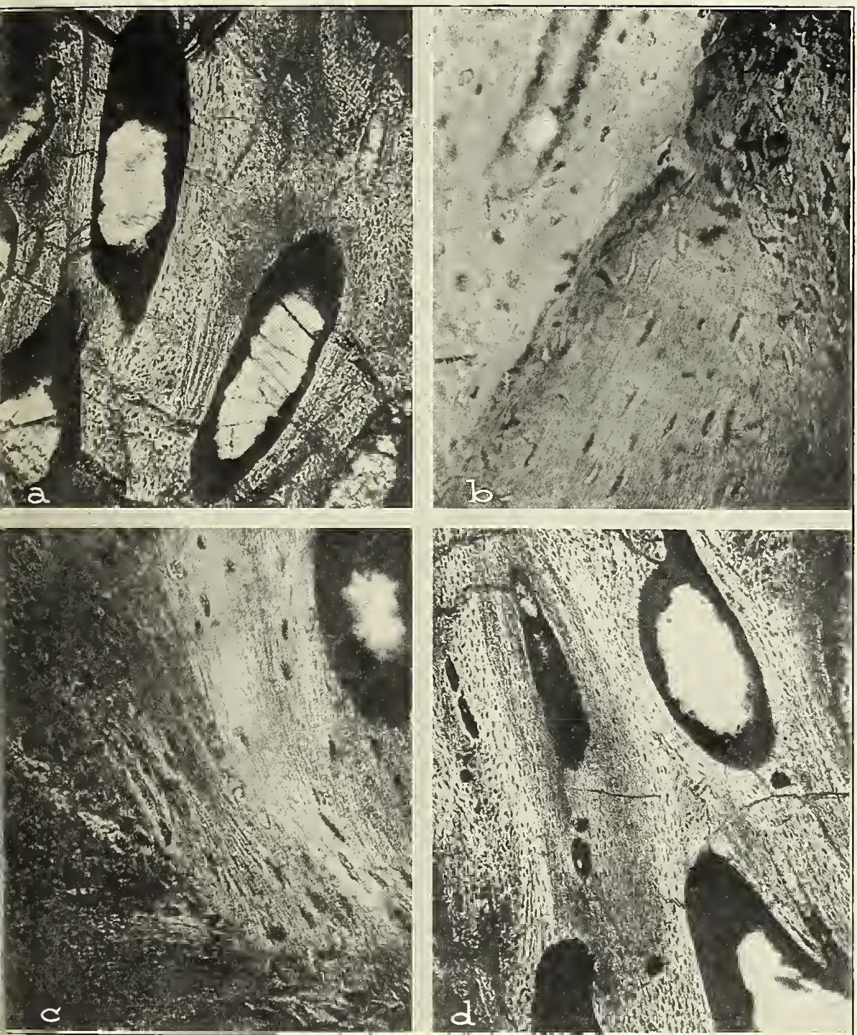


Plate XXXIII

PLATE XXXIV

PLATE XXXIV

The arm bones of a mosasaur from the Cretaceous of Kansas, (compare with normal bone, Fig. 18), showing lesions resembling those of osteoperiostitis. The large bone is the humerus, the other probably a radius. The rough surface of the bone indicates its pathology. Normal, well preserved specimens of these bones are quite smooth. The lesions extend to the articular surfaces. Specimens the property of the Kansas University Museum.

Plate XXXIV

PLATE XXXV

PLATE XXXV

THE OLDEST KNOWN FIBERS OF SHARPEY

a. An area of one of the lesions shown on the humerus of a mosasaur, Plate XXXIV, showing osteoid tissue. The black spots are the lacunae which have no canaliculi, or but very short ones. The large dark stripe in the lower left hand corner is a post-fossilization crack. The lines seen in the lower right hand corner are the fibers of Sharpey, the oldest occurrence so far known. See Plates XXXVI and XXXVII for further details of the histology of these fibers. The photomicrograph is X 300.

b. High power view (X 300) of an area around the post-fossilization crack, showing the nature of the perforating fibers and the lacunae.

c. Another area of the mosasaur humerus where, between vascular spaces, bundles of perforating fibers are abundant. X 70.

d. Sawn section of the humerus, Plate XXXIV, showing in the dark band on the left the sharp distinction of the pathologic bone. X 4.

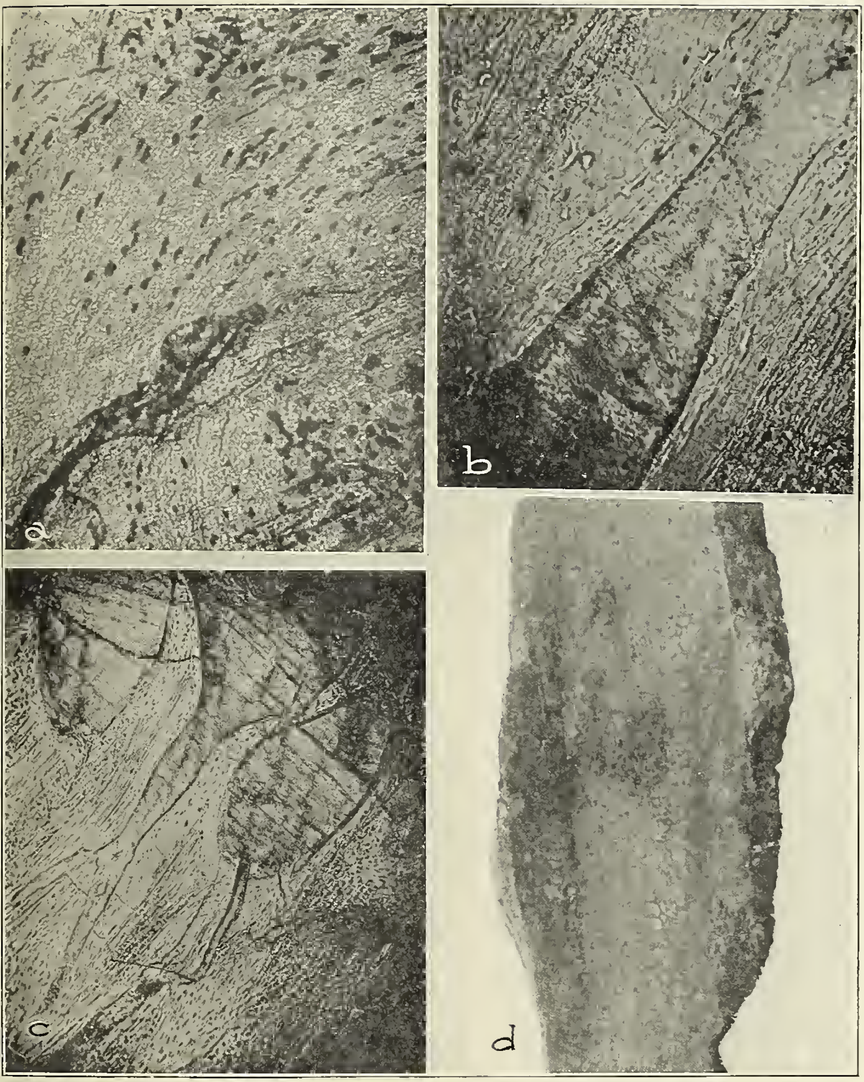


Plate XXXV

PLATE XXXVI

PLATE XXXVI

Microscopic study of a section from one of the lesions on the surface of the humerus shown in Plate XXXIV, showing bundles of perforating fibers of Sharpey, osseous lacunae, and vascular openings. The large clear space at right portion of the picture is a vascular channel filled with calcite crystals. X 300.

Plate XXXVI

PLATE XXXVII

PLATE XXXVII

High power microscopic study of another area of the same section as that shown in Plate XXXVI, showing the nature of the perforating fibers of Sharpey, seen in the long black strands running obliquely through the figure; the small lacunae with short canaliculi, which have no apparent arrangement.

Plate XXXVII

PLATE XXXVIII

PLATE XXXVIII

HISTOLOGY OF MOSASAUR BONE

a. Portion of normal bone, showing numerous large vascular channels, taken from the wall of an alveolus on a normal pterygoid of a mosasaur from the Cretaceous, Niobrara Chalk, of Kansas. X 70.

b. Enlarged view (X 300) of one of the primitive vascular channels of the bone shown in "a" representing an early type of Haversian canal, around which the lamellae and lacunae are concentrically arranged.

c. The lamellae and lacunae are especially clear in this portion of the same normal bone. The section is so thick that two or more layers of lacunae are seen, in varying degrees of density. X 300.

d. The preponderance of vascularity in the lesion of osteoperiostitis on the mosasaur humerus, Plate XXXIV, from the Cretaceous of Kansas. X 70.

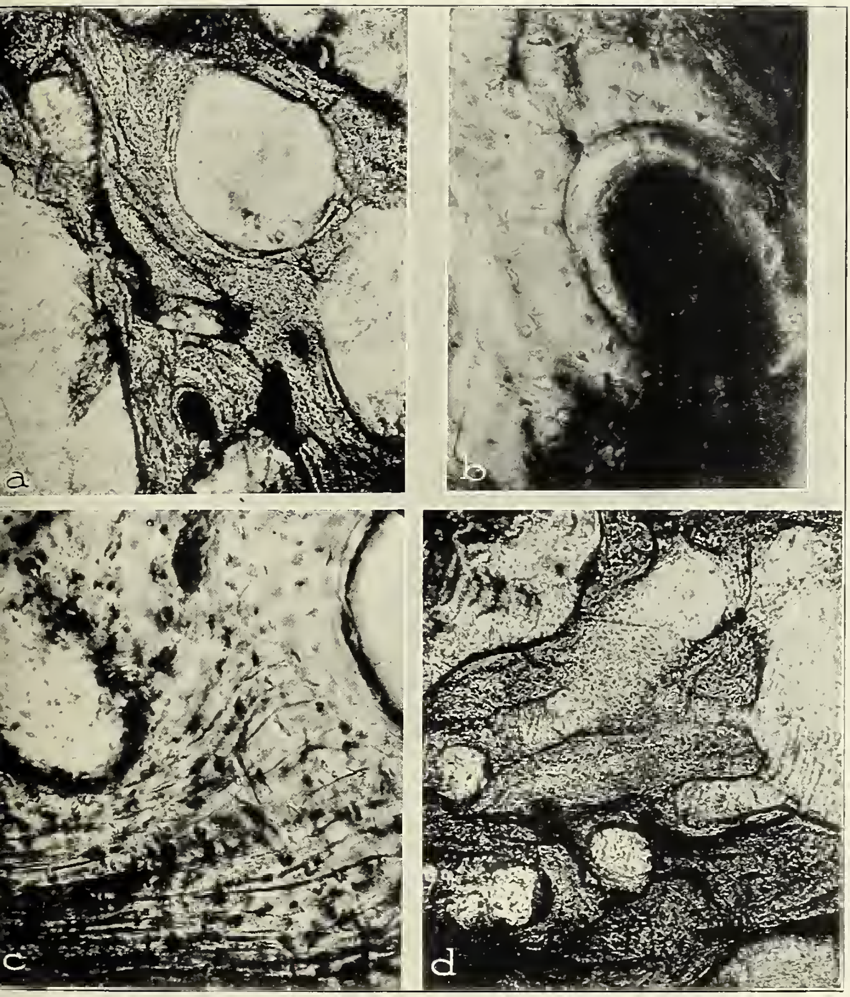


Plate XXXVIII

PLATE XXXIX

PLATE XXXIX

A CRETACEOUS OSTEOMA

a. Photograph of the dorsal vertebrae of *Platecarpus*, a Cretaceous mosasaur from the Niobrara chalk of Kansas, showing to the left the unique osteoma.

b. Photomicrograph X 70 of a portion of the osteoma showing large vascular spaces and slender trabeculae of bone in which are to be seen the lamellae and lacunae.

c. A sawn median section through the body of the vertebrae showing the close union, better shown in Plate XL, of the osteoma to the bone. The osteoma is on the left above the middle.

d. Enlarged photomicrograph, X 300, of one of the above trabeculae showing nature of lamellae and lacunae.

PLATE XXXIX

PLATE XL

PLATE XL

A SAWN SECTION THROUGH A FOSSIL OSTEOMA

Magnified drawing (X 8) of a sawn section, the shaded area shown in "d," Plate XLVIII. The osteoma which lies at the top of the drawing is seen to grow out of the body of the vertebra and grow backward along the vertebra. The line of demarkation is clearly evident.

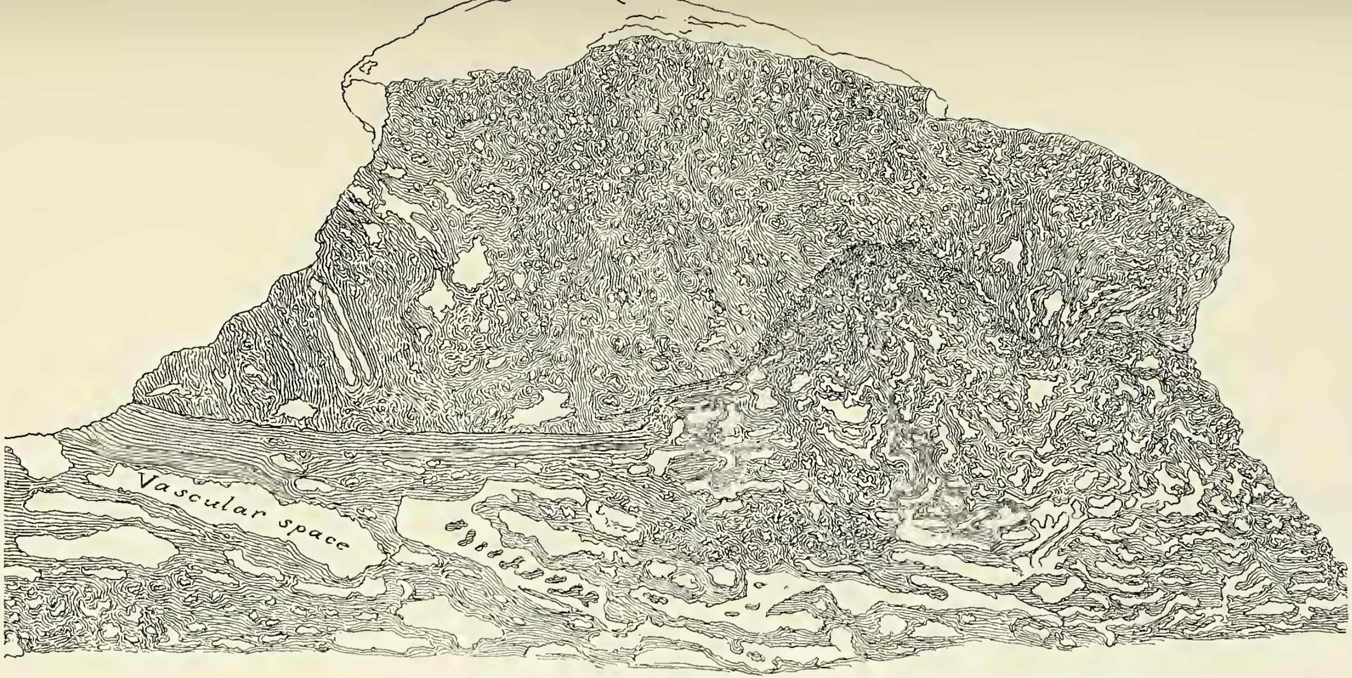


Plate XL

PLATE XLI

PLATE XLI

MULTIPLE ARTHRITIS

a. Diseased (below) and normal (above) metatarsals of a Kansas Cretaceous mosasaur. The diseased bone is notably shortened, flattened and broadened, with deforming arthritic lesions, carious roughening and a large terminal necrotic sinus. Originals in the Kansas University Museum of Natural History. Enlarged.

b. Terminal phalanges of big toe of a mosasaur, *Platecarpus*, from the Cretaceous of Kansas, showing in a slightly enlarged view the nature of the arthritic lesions. Original in the Kansas University Museum of Natural History.

c. Multiple arthritis in the phalanges of a large swimming reptile, a mosasaur known as *Platecarpus* from the Cretaceous of Kansas. The diseased bones are arranged around a normal metatarsal.

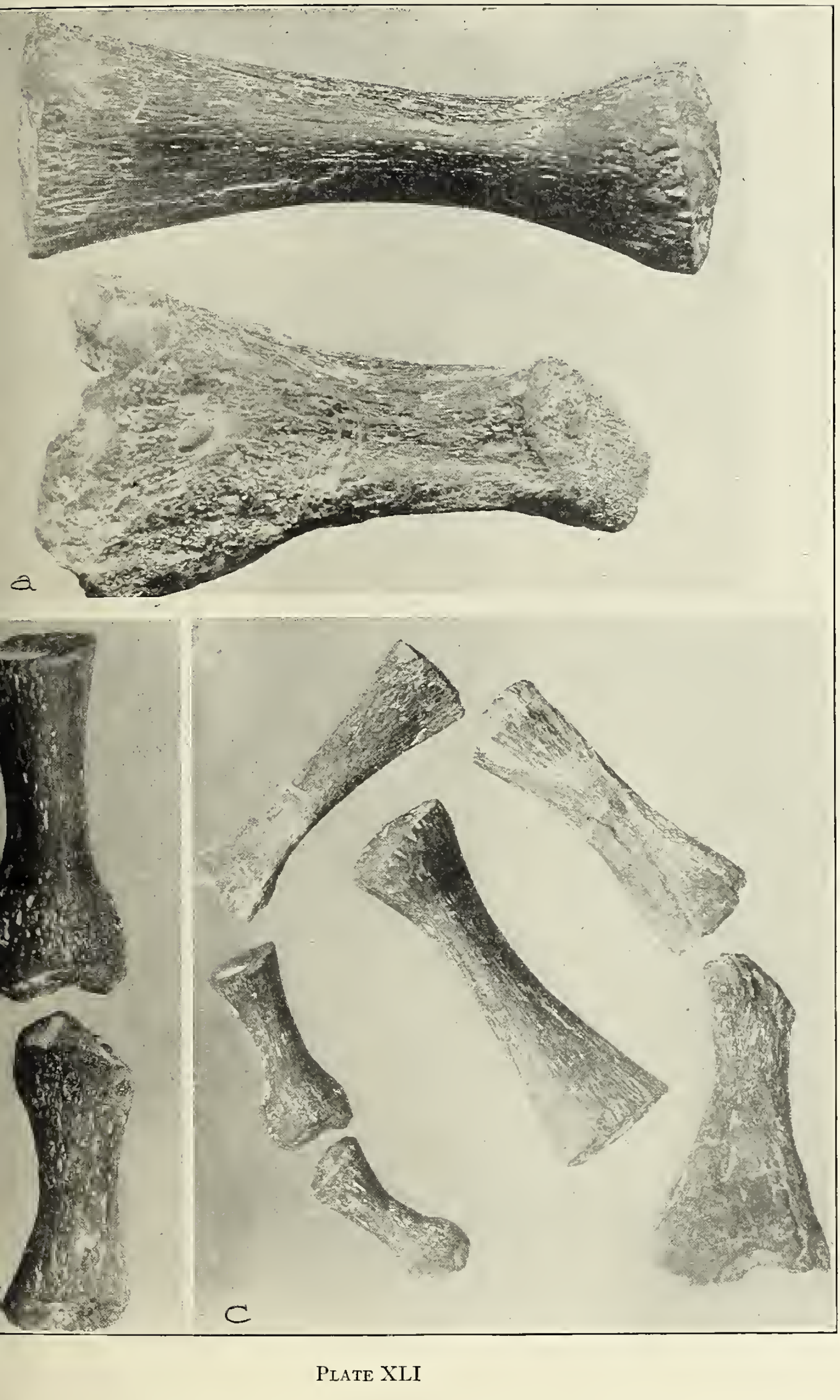


PLATE XLI

PLATE XLII

PLATE XLII

PLEISTOCENE PATHOLOGY

a. Diseased vertebra of *Smilodon*, from the Pleistocene deposits of California.

b. Osteomyelitis in the ulna of an American Bison, from the plains of Kansas, showing near the middle of the picture the junction of normal and pathologic bone. X 100.

c. Haversian canals in pathologic bone, showing in vertebra at "d," in lesion of spondylitis deformans. X 200.

d. Vertebra of saber tooth cat showing marginal lipping of spondylitis deformans. Pleistocene of California. See also Plate XLIII, d.

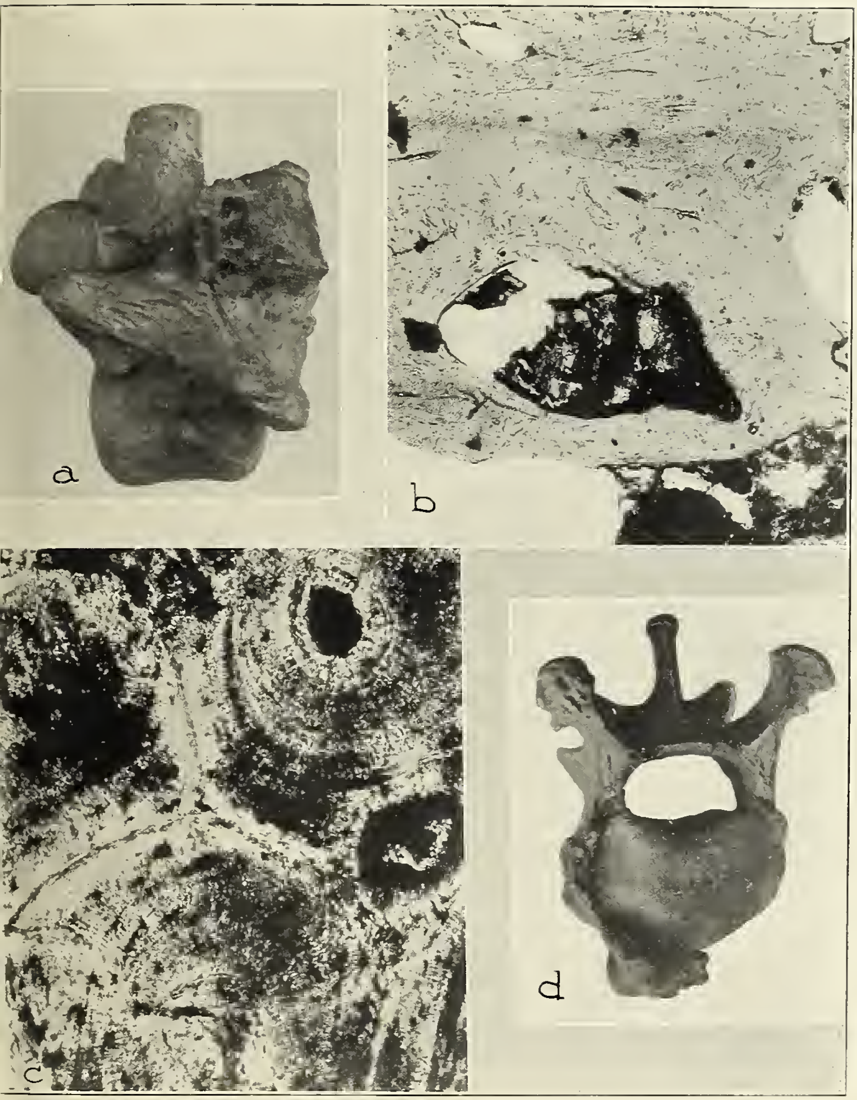


Plate XLII

PLATE XLIII

PLATE XLIII

HISTORY OF SPONDYLITIS DEFORMANS

a. Spondylitis deformans in a recent human lumbar vertebra.

b. Spondylitis deformans in a lumbar vertebra of an ancient Egyptian, about 5,000 years old. (After Ruffer.)

c. Posterior view of a dorsal vertebra of a cave bear, *Ursus spelaeus*, from Europe, showing lesion of spondylitis deformans. Possibly 250,000 years old. (After Mayer.)

d. Lateral view of a dorsal vertebra of a saber-tooth cat, *Smilodon*, from the Rancho la Brea, Pleistocene, asphalt beds, of California, showing characteristic lesions of spondylitis deformans.

These four figures show the characteristic lesions of this form of arthritis at different periods of the history of man and animals, covering approximately one-half a million years. So far as external appearances go there have been no changes since early Pleistocene at least. Similar lesions of greater antiquity have also been seen.

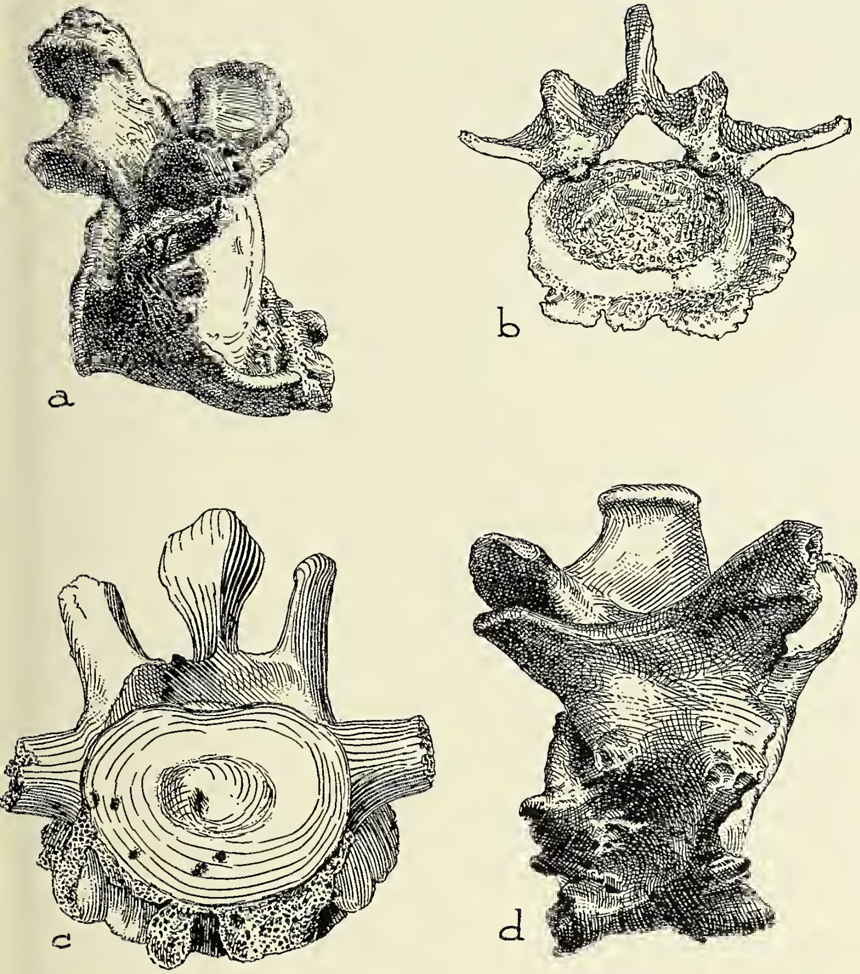


Plate XLIII

CHAPTER VI

CARIES AND ALVEOLAR OSTEITIS AMONG FOSSIL VERTEBRATES

Caries in Permian vertebrates. Dental disturbances among extinct reptiles and mammals. Caries in the Mastodon. An abscess in the Mastodon. Dental caries in the Mastodon. Premaxillary lesion in an African gorilla. Descriptions of Figures 19-22 and Plates XLIV-XLVI illustrating Chapter VI. Figures 19-22 and Plates XLIV-XLVI.

Diseases of the teeth and alveolae, as well as carious lesions of the skeleton, are fairly common among fossil vertebrates, being known in nearly every geological period from the Permian to the Recent. Renault has discussed caries of bones, scales, and teeth among the fish of the Permian of France, basing his observations on materials from coprolites of the Autun basin. A large marine reptile, one of the Cretaceous mosasaurs of Belgium, shows in the left mandibular ramus extensive evidences of this form of pathology. The mandible of a three-toed horse, *Merychippus campestris*, shows possible evidences of the ravages of actinomycosis, as well as an alveolar osteitis which has resulted in the absorption of the alveolar margins and the exposure of the roots of the teeth; a result today in cases of pyorrhea. Caries has been noted by Leidy and Hermann in the Pleistocene elephants. An alveolar disturbance in the Cohoes mastodon was noted by Hall. The early cave bears of Europe and many other fossil vertebrates show ravages of these two types of pathology. Teeth of primates from the Bridger Eocene of Wyoming are said to show dental disturbances. The early races of man were singularly free from these two diseases, although alveolar fistulae are evident in ancient human remains from England.

The nature and distribution of dental defects in ancient man, from an anthropological viewpoint, have been interestingly discussed by Lenhossek,[1] who reviews the evidences of disease but does not give any detailed account of the structure of the pathological lesions, and he deals with other pathology than that of caries. Cotte,[1a] also,

[1] M. v. Lenhossek: Die Zahnkaries einst und jetzt. Archiv für Anthropologie. N. F. Bd. xvii, 44-66, 5 figs. 1919.

[1a] Ch. Cotte: La carie dentaire et l'alimentation dans la provence prehistorique. L'homme prehistorique. 3e annee, 1905, 75.

has discussed the question of dental caries in prehistoric times. The entire subject of Paleolithic and Neolithic evidences, however, needs to be restudied and more adequately discussed from the viewpoint of pathology. Ruffer (1920) has presented the most adequate study of this phase of paleopathology, restricting his observations to the lesions seen on the remains of ancient Egyptians.

The oldest indication of *caries* is that described by Renault[1b] from Permian material. His results are in Chapter IX, in connection with the account of fossil bacteria.

I have stated elsewhere that caries of the teeth is fairly common among fossil vertebrates, yet a more careful investigation into the matter reveals the interesting fact that it seems to be the rarest form of pathology in ancient times. It is true that Dollo in the mosasaurs, Renault in fishes and Leidy and Hermann in the Mastodon, have described undoubted examples of dental caries, yet it seems not to be common. Experienced collectors of fossil mammals have never seen a carious tooth. Dentinal tubules in sections of a tusk of *Mastodon obscurus* seem to be filled with bacteria and there are undoubted carious spots on the edge of the dentine.

CARIES IN PERMIAN VERTEBRATES

Since this subject is dealt with at some length in Chapter IX, under the heading "Fossil Bacteria analogous to those which produce dental Caries" where is given a careful account of Renault's studies, the reader is referred to that section for a discussion of the subject. No new observations have been made since Renault wrote.

DENTAL DISTURBANCES AMONG EXTINCT REPTILES AND MAMMALS

There have not been described from American deposits any examples of dental caries among fossil reptiles, so far as I can learn. Abel (1912, p. 95) says Dollo has described an example of dental caries in the lower jaw of an extinct, Cretaceous, swimming reptile, *Mosasaurus*, No. 1503 of the Brussels Museum. The same jaw shows also alveolar changes indicating pyorrhea. It is interesting to observe that dental disturbances and rheumatism were present among Cretaceous animals, millions of years ago, lending some favor to the present theory of *focal infections*, though of course our knowledge of such Cretaceous pathology is too uncertain to be of great value. The above-mentioned mosasaur is the only example of dental caries of which I can learn

[1b] Bernard Renault: Sur quelques Microorganismes des Combustibles fossiles. 1900, pp. 316–323.

ımong extinct reptiles. There are undoubtedly more such cases and uture observations will serve to complete our knowledge of the history of this disease.

Among other vertebrates dental caries has been observed in cave-bears. An alveolar fistula is referred to by Abel (1912) as occurring in he right premaxillary in the skull of a mammal, *Eosiren libyca* Andrews which has produced some pathological changes in the bone. The original of this is in the museum at Munich and was collected by Professor E. von Stromer. I have seen an incisor of a camel (Figure 22) from the Pliocene, Snake Creek Beds, of Nebraska, which appears to show ravages of dental caries but it is uncertain whether it is not due to some other cause. The root of the tooth has several excrescences of osteodentine, similar to those figured on the whale's tooth.

An Eocene mammal, *Phenacodus primaevus*, a primitive ungulate, collected on the Gray Bull Creek, Wasatch Eocene of Wyoming, No. 15274, American Museum of Natural History, shows an accessory cusp on the second lower molar on the lingual surface of the left side.

The lower jaw of *Megalohyrax*, from the Fayum of Egypt, No. 14460, American Museum of Natural History, shows an anomaly in the transverse placing of the fourth premolar, which is bilaterally symmetrical. The position is probably due to mechanical compression of adjacent teeth since these teeth are the last to be erupted.

In the Princeton Museum is a small marsupial from Patagonia showing injury to the canine, with extraction of tooth and ingrowth of bone over the alveolus.

A Miocene rhinoceros tooth from Nebraska exhibits a peculiar form, probably due to the fact that it was crowded in the jaw and may not have erupted.

A Pleistocene mammoth molar, in the University of Kansas, presents an interesting form of disturbance. It is bent almost into a semicircle, though otherwise normal.

The above references are mere notes on the occurrence of dental disturbances and serve only as an introduction to the subject. It is well worthy of a special study by some one who is acquainted with dental anatomy.

The only remaining example, known to me, is interesting from the standpoint of alveolar osteitis, there being no changes in the teeth themselves, save those due to the exposure of their roots by the absorption of the alveolar processes. This example is the lower jaw of a fossil horse, *Merychippus campestris* (Plate XLIV). The osteitis in-

dicates the ravages of pyorrhea. In an earlier discussion I figured one of the teeth of this species as being carious, but more careful examination of the specimen reveals the fact that the supposedly carious spot is a post-fossilization fracture.

CARIES IN THE MASTODON

An example of caries has been described in a mastodon tooth from the Pleistocene of Florida. Leidy[2] in 1886 directed the attention of the members of the Philadelphia Academy of Science to a specimen consisting of the posterior portion of a last upper molar tooth of a Mastodon, which he had attributed to a species under the name *M. floridanus*. It is remarkable from the circumstance that it apparently exhibits the result of caries, a condition which Leidy had never previously observed in extinct animals, although he had seen, studied, and described many thousands of specimens. The supposed caries appears as an irregular excavation immediately above the crown of the tooth, about a quarter of an inch in depth. The mouth of the cavity is elliptical, extending one and one-fourth inches transversely, and one-fourth of an inch vertically. The surface of the cavity was irregularly eroded.

AN ABSCESS IN THE MASTODON

The famous Cohoes Mastodon, mounted in the State Museum of New York, Albany, exhibits a pathological condition in the right ramus of the mandible,[3] which carried but a single tooth.

> On the outer surface of the right ramus beneath the coronoid process, there is a perforation in the bone of one tenth of an inch in diameter and which can be penetrated to the depth of two inches. The portion of bone surrounding this opening is corrugated, as if ossified from several centers or nuclei, the laminae presenting an irregular concentric arrangement. From the position and appearance of this opening it is quite natural to infer that there had been an abscess in that jaw, or disease and decomposition of the undeveloped sixth molar.

[2] Joseph Leidy, an eminent American paleontologist, biologist, and anatomist, 1823–1891. He was one of the early students in the field of American vertebrate paleontology in which he attained great distinction. He is the author of numerous large memoirs on the paleontology of the vertebrates: *The Ancient Fauna of Nebraska or a Description of Remains of Extinct Mammalia and Chelonia, Washington, 1852; The Extinct Mammalian Fauna of Dakota and Nebraska, Including an Account of Some Allied Forms from Other Localities, together with a Synopsis of the Mammalian Remains of North America, Philadelphia, 1869; Contributions to the Extinct Vertebrate Fauna of the Western Territories, Washington, 1873.*

[3] James Hall: Notes and Observations on the Cohoes Mastodon. 21st Ann. Rpt. of the Regents of the Univ. of the State of N. Y., on the Condition of the State Cabinet of Nat'l Hist., Albany, 1871, 99–148, 7 pls, Pathologic mandible figured on Plate 7.

A section was later made of the jaw which corroborated this supposition, altho the opening was not so large as had been expected, possibly indicating that the disease had occurred during early life. The failure of the posterior right molar to develop affected the symmetry of the entire head, and the face of the creature is decidedly asymmetrical.

DENTAL CARIES IN THE MASTODON[4]

Defects of the teeth are seldom found among fossils and are rare in living animals. Geologically, the oldest defects are those parasitic borings which are found, according to Rothpletz, in the so-called Conodonts which are calcareous cuticular teeth of Silurian worms (*Drepanodus* Pander) from the lower Silurian of the Russian Baltic Province. The researches of Rohan and Zittel on Conodonts revealed these passages in thin sections of the teeth. Of additional interest in this connection is Jaekel's discovery of thread mould (*Mycelites ossifragus* Roux) in the dentine of rostral teeth of *Pristiophorus suevicus* Jaekel from the Miocene of Baltringen as well as in the dental substance of other Selachia from the Tertiary, Upper Cretaceous and Jurassic. Other little known defects owe their origin to mechanical causes and Virchow has described such cavities in the canine teeth of two anthropoids, an orang-utan, and a chimpanzee.

At the meeting of the Naturalists' Society in Berlin Hermann had the good fortune to submit a great number of defective teeth from certain collections in Berlin. These were deformed partly by abrasion, partly by fracture, and some of them showed an opening into the pulp cavity.

Of the fishes, the Jurassic and Tertiary Pycnodonts were discussed as well as mammals (with the exception of the domestic and menagerie animals), the genera *Hyaena*, *Meles*, *Ursus*, (by reference to recent and fossil species) *Cervus* and the anthropomorphs (by reference to *Simia satyrus* L., *Gorilla gorilla* Wyman and *Anthropopithecus troglodytes* Bloch).

The question was also brought up as to whether carious defects could be detected, although no undoubted carious defects have been

[4] Observations on this subject, discussed in this section, are given here as a free translation of a paper by Rudolf Hermann (1908). His contributions to this subject are:

Rudolf Hermann: 1907a—Ueber das Vorkommen hohler Zaehne bei fossilen und lebenden Tieren. Sitzb. d. Gesell. naturf. Freunde zu Berlin, Jahrg., 1907, 195–201. 1907b—Weitere Beobachtungen ueber Zahndefekte bei fossilen und lebenden Tieren. Ibid., 284–287. 1908—Caries bei Mastodon (Pleistocene of Ohio) Anatom. Anz., xxxii, no. 13, 305–313, pl. and figs.

found among living wild animals. Yet the possibility of such an occurrence is evident from the standpoint of veterinary medicine.

The question brought up at this discussion as to whether tooth-defects occurred among living wild animals, had an unexpected result a few weeks later. Dr. Stremme found, through an examination of a collection of mammals, a tooth of *Mastodon americanus* Cuv. from the Pleistocene of Ohio in North America.

This tooth, the second last molar of the left lower jaw, exhibits upon the chewing surface and on the lateral side a defect which can only be due to caries. The tooth has a greatest length of 12 cm. and is about as high. Of the three arches, the anterior is provided with a cavity, which is transversely placed. The second arch shows two smaller cavities, which are connected in the middle of the tooth with each other and with the cavity of the first arch. A third cavity is found in the second part. It was formerly bounded by a bridge, a millimeter thick, which binds the two cusps of the second arch as well as the inner wall of the third arch, into which it had eaten out a cavity. On the inner cusp of the third arch is the beginning of a fourth defect, in a small fossa, obliquely oval.

If we compare this tooth with a sound one, we would notice that in contrast to the normal chewing surfaces, the foremost arch, especially on the inner cusp, is less strong than the following arch. The falling off of the chewing surface from the front to the back causes one to believe at first that the matter in question was a tooth of the right lower jaw.

A more careful comparison of teeth embedded in the jaw of an American Mastodon reveals that the tooth in question belongs to the left lower jaw. A more exact comparison of the two teeth shows a common increase in chewing surface of the buccal surface. To the increase of the chewing surface in a lingual direction on the teeth of the lower jaw, there is a corresponding increase in the upper jaw toward the cheek; therefore, it is not a consequent of the stronger chewing, but rather the cause of it.

In regard to this, there are particularly important differences to be noticed. On the foremost arch of the diseased tooth is shown, as already explained for the inner cusp, only very slight traces of attrition, while it had already made further progress on the sound tooth. The outer cusp, however, is alike in both strongly abraded. The second arch is also almost equally worn on both teeth. The second inner cusp of the diseased tooth shows only a quadrangular depression, which

in contradistinction to the sharp angular carious defect, is bounded by rounded nodes.

The third arch is strongly abraded on the diseased tooth, while on the sound tooth only one weak abrasion of the outer cusp is visible. The talon-like process on the distal end of the sound tooth is almost entirely missing from the diseased tooth. It is here disturbed through the hollowing of the distal surface by the further progress of the carious necrosis. That the fractures on both teeth are secondary appearances, which originate from the drying of the teeth in the air, I need not consider. In *Mastodon americanus* Cuv. and a few related species, there is such a variation in the number of the teeth that the deciduous molars become pushed off by the protruding back molars and fall out so that only three molars are being used in chewing.

The teeth were gradually abraded down to the neck of the tooth and I have examined many jaws in which only fragments of the first molars were present, while the alveolae in the anterior part are almost entirely filled up. In connection with the acquisition of permanent teeth, it is to be noticed that the degree of attrition increases strongly antero-posteriorly, that though the small foremost part of the tooth had already been in use for some time, the posterior part is used first.

If the manner of attrition varies from this rule so far as the tooth before us is concerned, then it is to be explained on the simplest basis of the form of its opposite tooth. One could also think that our Mastodon on that account suffered violent pains.

I might add that the opposite tooth showed strong carious defects and that only a slightly abraded first inner cusp corresponded with the cavity of the second upper molars. The condition of the second inner cusp also supports this interpretation. The quadrangular cavity which it possesses, I might have perceived as a defect due to use which became abnormal through the abnormal form of its opposite.

The defects of the proximal surface make is probable that the neighboring teeth, M_1 and M_3 were diseased, for it is hard to believe that the remains of food by decaying would not result in the extension of the cavity into the neighboring teeth.

A microscopical examination of the Mastodon tooth reveals no indication of either Bacteria or pulp, since all organic substances have disappeared in the process of fossilization. Perhaps the existence of *Leptothrix* would be revealed in a thin section. In order not to harm the object, I have refrained from making a section. At the same time the

invasion of *Leptothrix* from recent investigations follows disease of the tooth and therefore the reference to this fungus is of consequence.

Moreover, I have shown the tooth to experienced men for their opinion. Dr. Ritter of Berlin who helped me with my first investigation on the occurrence of defects of the teeth of fossils and living animals, confirmed, as the other men, that the defects of the Mastodon teeth must be looked upon as caries.

Caries in domestic and menagerie animals has been long ago recognized. But according to Magitot and Miller, it is much more violent in the domestic dog than in human races.

For its occurrence in wild living animals, I have discovered from some very general statements, which I have already included in another place, only two undoubted cases. One of them was discussed in 1891 by Bush, in a discussion "On the dentition of aquatic mammalia." In an underjaw tooth of the whale, *Physeter macrocephalus* L., are found "cavities on the buccal irregular inner surface if they were not due to boring of some aquatic insect must be regarded as carious cavities."

Miller, whose investigations and observations on the parastic nature of caries, as I had been informed, have been found in learned circles to be generally accepted and recognized, had removed this conception, because, first, the cavities in the whale's tooth does not show any of the characteristic carious marks, and secondly, the presence of acids, which is necessary to the decalcification of the tooth, is hard to explain.

The other case was described by Miller in 1893. It is concerned with many carious molars in the skull of a *Manatus senegalensis* Desm. from the collection of the Berlin Dental Institute.

Miller cites from Brehm's "Tierleben" the observation that the Manatees after a time of rich feeding, which consists of plants, go to sleep in a stream with the snout out of the water. During the duration of this sleep, according to Miller, a fermentation of the food remains begins. Miller gives the characteristic picture of a section made by him through a carious *Manatus* tooth, showing pictures of some bacteria in the carious tissue. That caries also occurs in wild living animals is not surprising according to the dominant conception of the existence of this disease. If certain fruits which contain acid cause a decalcification in the teeth, if some diseases, as rheumatism, gout, intestinal disease, and others, disturb the teeth through an acid reaction of the saliva, these are then the causes which can attack the free living

animals just as well as domestic animals and human beings. And as soon as the tooth softens, the bacteria immediately begin their dissolvent process of necrosis, for they naturally find their way into the mouth of an animal just as easily as into the human mouth.

A mechanical injury of the tooth or an exposure of the pulp by abrasion is very seldom the cause of caries. Under the relatively frequent cases of this kind, which I have seen to date, are found none which have resulted in caries, although the injured animal suffered the loss of the tooth; therefore, it appears to me possible that the retention of unused food in the mouth in many observed cases has been the cause of the production of cavities, produced by the decalcification and softening of the tooth substance, even though the animal is healthy.

PREMAXILLARY LESION IN AN AFRICAN GORILLA

An adult, male gorilla skull preserved in the Field Museum exhibits a lesion which lends some insight into the traumatic changes which take place among wild animals. An examination of this well-developed skull indicates that the right incisors and canine are missing and the alveolae have been either cut or bitten off or absorbed. Possibly some carnivorous animal captured the gorilla, when young, and bit out a piece of the upper jaw. There was no subsequent infection, since the thin, paper-like conchae of the nose are as clear and free from all osteitis as can be. The loss of the teeth, however, resulted in the development of an interesting asymmetry of the face and a marked deflection of the nasal septum, recalling in this respect the famous Cohoes Mastodon referred to on a preceding page. The African gorilla appears to have been otherwise free of all harm, since the walls of the multiple paranasal sinuses show no effect of catarrh, which the deflected median nasal septum would lead one to suspect.

DESCRIPTIONS OF FIGURES 19-22 AND PLATES XLIV-XLVI ILLUSTRATING CHAPTER VI

FIGURE 19

Molar of a recent horse showing pathological excrescences of osteodentine on the root.

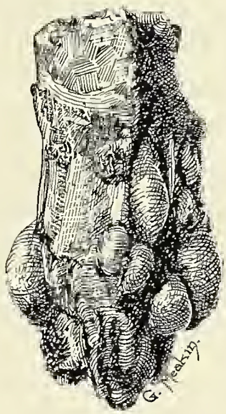


Figure 19

FIGURE 20

Figure 20

Joseph Leidy. American Anatomist and Paleontologist, 1823–1891.

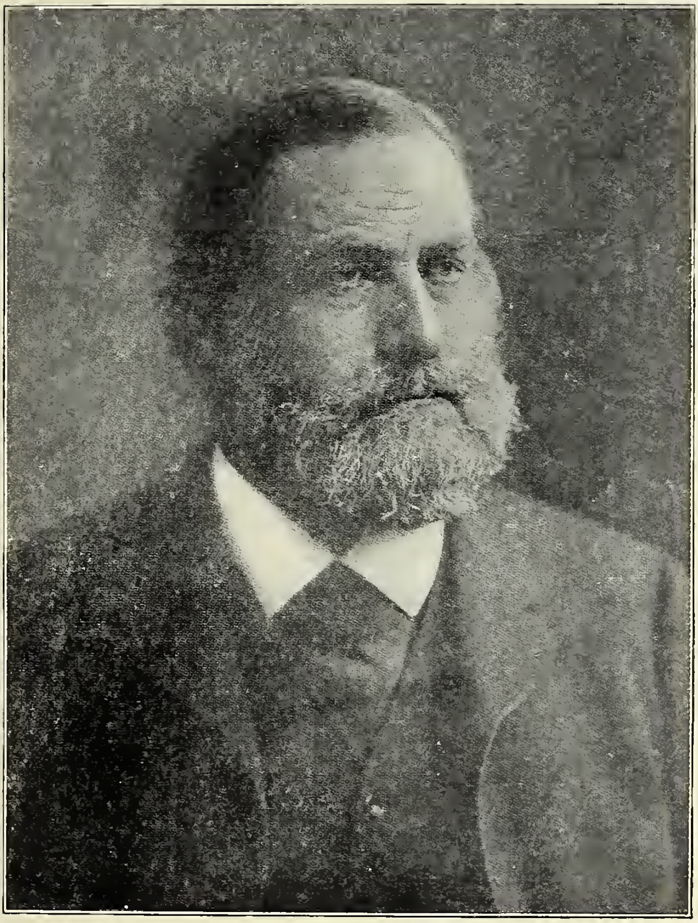


Figure 20

FIGURES 21-22

FIGURE 21

Median Sagittal Section of Whale's tooth (Cachelot) showing pulp stones and dentine exostoses. Area outlined in broken lines shown enlarged in fig. d, Plate XLVI.

FIGURE 22

Incisor of a camel from the Pliocene of the Snake Creek beds of Nebraska, showing in the cleft in the dentine a possible instance of dental caries. There are two excrescences of osteodentine on the root. Specimen loaned by Mr. Harold J. Cook. Enlarged.

Figure 21

Figure 22

PLATE XLIV

PLATE XLIV

PATHOLOGY OF A THREE-TOED HORSE

Two views of the mandible of a three-toed horse, *Merychippus campestris*, from the Miocene, about 1,500,000 years old. The figures show in the absorbed alveolar margins evidences of pyorrhea. The swelling in the jaw, so evident in the lower figure, is indicative of a fistula, possibly suggesting the presence of actinomycosis in its early stages.

Specimens in the American Museum of Natural History. Courtesy of Dr. W. D. Matthew.

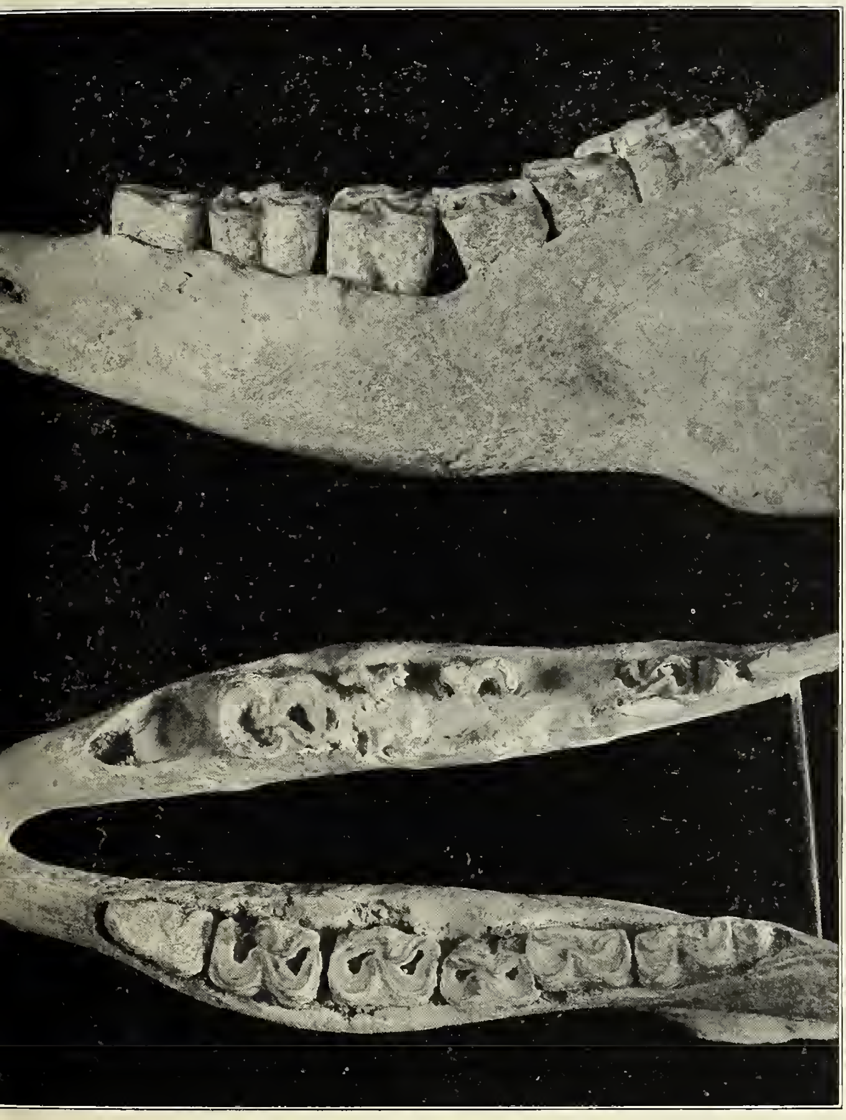


Plate XLIV

PLATE XLV

PLATE XLV

AN ANOMALOUS MASTODON MOLAR

Various teeth of the Mastodon from the Pleistocene of North America, preserved in the U. S. National Museum. An anomalous molar, shown in the lower left hand corner, is compared with normal teeth. Reduced.

Plate XLV

PLATE XLVI

PLATE XLVI

PATHOLOGY OF TEETH

a. Median sagittal section of a recent elephant tusk showing a lesion, possibly an odontoma in the basal portion. Wistar Institute Museum. Photo by Dr. C. H. Heuser.

b. Diseased tooth of cachelot whale with exostoses of dentine; pulp cavity filled with osteodentine. Such exostoses are commonly seen on the roots of cachelot whales and the present case is merely an exaggerated instance of a common occurrence among toothed whales. Recent. Specimen presented by Dr. J. M. Clarke, New York State Museum.

c. An odontoblast in the root of a human tooth. Normal, 200.

d. Photomicrograph of area of exostosis outlined in Figure 21, of whale's tooth, showing arrangement of layers of dentine. X 100.

Figures a and b are mounted with the crowns of the teeth downward to call attention more prominently to their pathology.

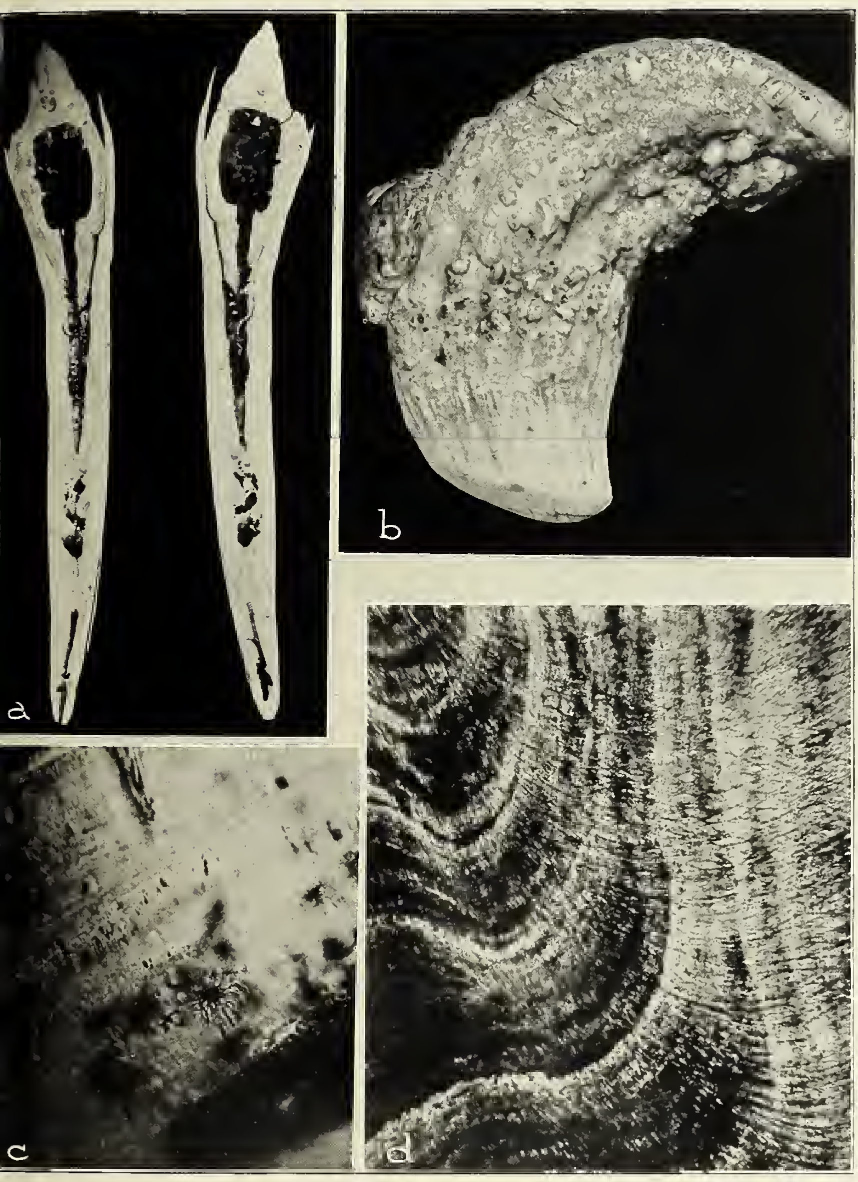


Plate XLVI

CHAPTER VII

CHRONIC INFECTIONS AMONG FOSSIL VERTEBRATES

Osteomyelitis in the Permian. Necroses and hyperostoses in the dinosaurs. A large necrotic sinus in a mosasaur. A symmetrical lesion in an early dog. Mesozoic pathology. Actinomycosis in a fossil rhinoceros. Hyperostoses or pachyostoses (Giantism) in ancient animals. Osteomalacia in an Eocene carnivore. Traumatic lesions and other pathology of the Pleistocene mammals. Skeletal anomalies among fossil vertebrates. Descriptions of Figures 23–25 and Plates XLVII–LVIII illustrating Chapter VII. Figures 23–25 and Plates XLVII–LVIII.

The lesions discussed in this chapter are of a miscellaneous character; necroses, exostoses, osteomyelitis, osteomalacia and other pathological results which are difficult to classify. Dental caries because of its rather special character is assigned to Chapter VI. Many chronic infections are definitely related to fractures and other traumatisms and many are discussed in Chapter IV. Spondylitis deformans is a special chronic affair which can readily be discussed with other deforming arthritides, but there still remain sufficient unclassified material for a special section. The lesions discussed in this chapter serve to show the great age of the types of pathological processes which they represent. They are not all assuredly infections of a bacterial nature, some of them being due to chronic irritations of another nature. The supposed example of actinomycosis in a fossil rhinoceros is due to infections of the ray-fungus and some of the lesions may be due to other forms of parasitism.

Necrotic processes are first evident among fossil vertebrates in the Permian long-spined reptile (Plate XV, a), in a Triassic phytosaur and in a Jurassic crocodile (Plate X, c and d). Necrotic sinuses are abundant among the fossil vertebrates from the Cretaceous and fairly common throughout the Tertiary, reaching a climax, so far as extinct animals are concerned, in the Pleistocene. This is due, not to any actual increase of disease during the later Tertiary perhaps, but to the fact that we know the Pleistocene vertebrates better. The graph (Figure 2) shows our knowledge of this condition and may not represent the actual state of affairs.

Exostoses, of course, often accompany necrotic processes as well as other forms of pathology, but in this chapter will be discussed those

special types of exostoses which accompany no known pathology and whose origin is obscure, as in the case of the *Triceratops* scapula, (Plate L, *b-c*).

OSTEOMYELITIS IN THE PERMIAN

The evidence regarded as osteomyelitis in the remains of a Permian reptile from Texas is based on a large tumified vertebral spine (Plate XV, a and XXI). It is always an interesting matter to be able to call attention to the earliest appearance in geological time of any phenomenon of nature which is common at the present time. It is especially important in ancient pathology to point out the similarity in form of the results of infective processes of ancient times with those of recent epochs. It is evident that the results of pathological processes have undergone no particular evolutionary change and one untrained in the study of fossil objects is able to recognize an example of osteomyelitis from the Permian if he is acquainted with modern pathology.

The specimen which shows this interesting phase of pathology is a posterior dorsal spine of a reptile of the *Edaphosaurus* type (Plate XIV, a) and was collected in the Red Beds of Texas by Mr. Paul C. Miller of the University of Chicago. The spine had been fractured near its base (shown at the point of the arrow, Plate XV, a) in a compound transverse break, the line of which is still evident. An infection ensued because of the breaking of the skin, although the line is a simple, direct fracture, which developed into a chronic osteomyelitis, which became entirely healed before the death of the animal since there is no evidence of a discharging channel and the sequestrum is not evident (Plate XXI). This produced in the shaft of the bone a sinus-filled tumefaction which is today so characteristic of chronic osteomyelitis.

The presence of these sinuses, which during life were doubtless filled with pus though the discharge had ceased long before death, argues for the presence of infective bacteria during the Permian such as have been demonstrated by the magnificent researches of Renault in the Paleozoic of France. Search through four microscopic transverse sections, taken at different levels, (Plate XXI) revealed bacteria in the enlarged canaliculi but there is considerable doubt as to their being of an infective nature, being more properly regarded as those of decay. These bacteria are more fully discussed in Chapter IX, under the heading, "Bacteria in the American Permian."

This spine of a Permian reptile is the oldest known vertebrate fossil showing the results of infection, which has been seen or described, as it

is likewise the oldest known example of osteomyelitis. These statements apply only to fossil vertebrates for I have not sufficient knowledge of invertebrate forms to make a sweeping statement concerning all fossil animals, but so far as my studies go I have seen no example of bacterial infection during the life of any Paleozoic species older than the Permian reptile to which this spine belongs. This of course brings up the question of the existence of a mild form of pathology during the early geological periods. The entire problem of early pathology is, however, still an open one and hasty conclusions must not be made on insufficient data.

NECROSES AND HYPEROSTOSES IN THE DINOSAURS

An interesting example of traumatic necrosis is seen in the ilium of a large dinosaur (Plate L, a), *Camptosaurus*, the skeleton of which is mounted in the U. S. National Museum and has been described by Gilmore, (1909, 1912). The injury is on the posterior end of the right ilium and has resulted in a deep necrotic sinus, accompanied by considerable hypertrophy of bone, as is the case in modern chronic infections. It is useless to speculate as to how the injury may have been received. Abel has suggested that the specimen represents a female and the injury was received during the breeding season, but it might easily have been due to another cause. (Figure 23.)

One of the most exaggerated cases of hyperostosis seen among the dinosaurs is that noted in the scapula of *Triceratops*, one of the three-horned dinosaurs from the Cretaceous of Wyoming. The hook-like lesion (Plate L, b) is situated on the broad visceral surface of the bone and there is no evidence of infection, but doubtless some chronic irritation produced the lesion. The visceral surface in these animals is normally perfectly smooth, since it slides over the ribs in walking. It is difficult to see how the animal could have moved about much since the process is long enough to have produced laceration of the pleura. Similar lesions are seen on modern human bone, and one is figured (Plate LII, b) on a femur. This lesion, however, was deeply covered by muscles and save in form does not compare with the cruel, hook-shaped process of the dinosaur scapula.

Other pathological lesions seen on dinosaur skeletons are described in Chapters IV and V.

The huge glyptodonts of the Pliocene and Pleistocene of South America, in spite of their heavy armoring of bone on skull, body and tail, were often subjected to injuries which became infected and pro-

duced extensive necroses in the bony carapace. Dr. Sinclair of Princeton suggested to me that these necrotic sinuses, examples of which are on exhibition in the Princeton Museum, were caused by injuries from the saber-toothed cat, which in attacking the glyptodont and finding himself baffled by the heavy, bony carapace, clawed and bit as best he could. If the giant Pleistocene cat's teeth and claws were as septic as the modern house cat's are said to be, sepsis may well have followed such an attack. Similar necrotic sinuses are evident, with a depth of nearly an inch, in the huge dermal plates of the giant dinosaur, *Stegosaurus*, which bore a large erect armament above his vertebral column. This necrosis is undoubtedly due to an injury, possibly from the bite of a carnivorous dinosaur. The specimen of this plate is in the U. S. National Museum of Washington.

A LARGE NECROTIC SINUS IN A MOSASAUR

The deep sinus (Plate XLVIII, a and b) seen in the articular surface of one of the arm bones of a swimming reptile, a mosasaur, from the Cretaceous of Kansas, may possibly be interpreted as a tuberculous infection, since it is difficult to perceive how such a necrosis may have been due to a traumatism, protected as the surface was by the adjoining bones. To say, however, that tuberculosis occurred in this geological period would be assuming too much since all diagnoses of fossil lesions must necessarily be suggestive of a modern condition and not a positive diagnosis of the pathology.

The mosasaurs were large swimming reptiles (Figure 16) and some account of their nature has already been given in Chapter V. The arm bone is doubtless a radius, though greatly deformed by disease. The necrotic sinus occurs at the upper pole of the bone, occupying nearly the entire articular surface. It is a deep, irregular, rough-sided pocket, surrounded by a lipped surface indicating the existence of an extensive suppuration. The accompanying hypertrophy and the nature of the sinus are shown in Plate XLVIII, b which is a drawing of a vertical section of the diseased bone. The necrosis undoubtedly indicates bacterial activity. The amount of osteohypertrophy is extensive, indicated by the blackened areas in the figure (Plate XLVIII). These dense areas are wanting in normal bone which are usually abundantly vascular.

A SYMMETRICAL LESION IN AN EARLY DOG

A comparison of the radii of two extinct dogs, *Daphaenus* and *Daphaenodon*, as they are represented in the mounted skeletons of these

'ossil carnivores in Carnegie Museum, reveals the fact, already noted ›y Hatcher in his memoir of Oligocene Canidae, that *Daphaneus* dif- 'ers greatly from its forebear in the possession of very curious sym- netrical lesions on the fore limb, near the ends of the radii. These bones n *Daphaenodon* are smooth. *Daphaenus felinus* the Oligocene dog from Nebraska, is almost unique in the possession of these tumor-like nasses (Plate LIII, b and c). Mr. Riggs has shown me similar lesions n the fore-limb of a small Miocene carnivore, but this example has iot been described. The lesions are not wholly symmetrical since the eft tumor-like mass is nearly twice as large as the right. Both lesions nd in four or five osteophytes. The nature of the lesions is entirely roblematical and no modern human examples of such things have een met with, so far as I can learn.

MESOZOIC PATHOLOGY

The following brief tabulation of Mesozoic pathology will aid in ppreciating the degree of progress disease had made at this time.

I. Arthritides:
- 1. Spondylitis deformans (Diplodocus, Camarasaurus, Tyrannosaurus).
- 2. Multiple arthritis (Rheumatoid in Mosasaur).
- 3. Arthritis deformans (with osteoma and periostitis).

II. Tumors:
- 4. Osteoma (Mosasaur).
- 5. Hæmangioma (Apatosaurus).

I. Necroses:
- 6. Necrosis with hyperplasia { Jurassic crocodile, Triceratops skull, Camptosaurus, Mosasaur radius.
- 7. Caries in Mosasaur.

V. Hyperostoses:
- 8. Alveolar osteitis (Mosasaur of Belgium-Dollo).
- 9. Exostoses (scapula of Triceratops).
- 10. Gigantism (hyperostosis in Nothosaur).
- 11. Osteoperiostitis (humerus of Mosasaur).

V. Fractures:
- 12. Skull in Mystriosuchus (Triassic).
- 13. Oblique fracture in humerus of Hypacrosaurus and subperiosteal abscess.
- 14. Simple fracture in rib of Dinosaur.
- 15. Fracture (?) of tail, accompanied by osteomyelitis.

This array of fifteen pathological results is a startling one. I do not y that this is *all* the pathology of the Mesozoic, but it is all I have seen heard described, and serves as a basis for future knowledge. This ray of diseased members argues for a long preceding history of path-

ology of which we are largely ignorant. The necroses and arthritides argue for the presence of Mesozoic pathogenic bacteria of various types which are otherwise unknown, although bacteria have been seen in an osteomyelitis from the American Permian.

It will be more satisfactory to discuss briefly the evidence on which the above classification is made:

I. Arthritides: This is a group term used to define all pathological results found in or around the joint surfaces of the limbs, vertebræ, and skull. The lesions are the result of a great variety of diseases.

1. Spondylitis deformans: This is a type of pathology found around the articular surface of the vertebrae. It is the result of inflammation in the vertebral ligaments, caused either by infection or injury. It accompanies Pott's disease (vertebral tuberculosis) and may cause a complete rigidity of the spine. Co-ossified vertebrae are often indications of this form of pathology. The united caudals of *Diplodocus* described by Hatcher and Osborn are clearly examples of this type. Other co-ossified vertebrae in the dinosaurs are due to different causes. Thus the co-ossified caudals of *Brontosaurus* mounted in the Carnegie Museum are not Spondylitis deformans, but osteomyelitis. Spondylitis deformans has a curiously satisfactory geological history, being known in the Comanchean, Cretaceous, Eocene, Miocene, Pliocene, abundantly in the Pleistocene, and very common in the Recent epoch.

2. Multiple arthritis (Rheumatoid): This form of pathology, involving the great toe of a large Kansas Mosasaur, is the only fossil example known to me. This is a sort of Mosasaurian gout or rheumatism which must have caused the old fellow some inconvenience.

3. Arthritis deformans: Only two examples of this form of pathology are known to me, both accompanying other pathological lesions. The articular surfaces are only slightly deformed.

II. Tumors: These pathological growths, neoplasms, are not due to a definite infection and arise from pre-existing tissues. Only two examples of tumors are known during the Mesozoic.

4. Osteoma: Seen on the dorsal vertebrae of a Kansas Cretaceous Mosasaur. Not to be confused with a hypapophysis, but is a true outgrowth of the vertebra.

5. Hæmangioma: This has been previously described and appears to be a true tumor. It occurs between two caudal vertebrae of a Comanchean Dinosaur.

III. Necroses: These are the definite result of bacterial or other infection. The various types can not be distinguished in a fossil condition. There are numerous examples known.

6. Necrosis with hyperplasia is present in the ilium of Camptosaurus in the U. S. National Museum and in a Mosasaur radius belonging to the University of Kansas.

7. Caries is not common among fossil vertebrates, although Dollo gives an example of it in the mosasaurs, and Leidy and Hermann have described it in the American mastodon. I have never seen an example of fossil dental caries.

IV. Hyperostoses: These are thickenings of bone, taking the form of outgrowths not classified in the preceding groups.

8. Alveolar osteitis, the result of pyorrhea, I have never seen in Mesozoic fossils, although Dollo has described it in a Cretaceous Mosasaur.

9. Exostoses are fairly common and assume a variety of forms.

10. The pathology of Gigantism, or extreme osseous hyperplasia, is suggested by Volz and Abel as an explanation of certain hypertrophied Nothosaur and fish bones.

11. Osteoperiostitis: This is a diagnosis assigned as the cause of the pathological excrescences seen in a Cretaceous Mosasaur from Kansas.

V. Fractures are of a variety of types, depending on the situation and the degree of pathology involved.

12. Skull fracture in the Triassic Mystriosuchus reported by von Huene. Occurs immediately anterior to the nares.

13. Oblique fracture with subperiosteal abscess seen in the humerus of Hypacrosaurus in the American Museum. A common form of pathology today. The bridge of bone present in the fossil humerus is due to an elevation of the periosteum by an enormous abscess capable of holding several liters of fluid.

14. Simple fracture, commonest type of fracture among fossil animals. An example in the mounted skeleton of Apatosaurus in Field Museum.

15. Fracture in tail of Brontosaurus with osteomyelitis.

ACTINOMYCOSIS IN A FOSSIL RHINOCEROS

The antiquity of the disease commonly known as "wooden tongue," "lump-jaw" and other phases of this infection is suggested by the swelling in the lower jaw of a three-toed horse, *Merychippus campestris* (Plate XLIV), from the Miocene. Since this specimen is a type of the species preserved in the American Museum of Natural History internal examination of the lesion is not possible. Nor is it at all certain that such an examination would aid in a correct diagnosis since the swelling may have been caused by a huge alveolar abscess. So far as I am aware this is the earliest suggestion of this form of pathology among fossil vertebrates but it is to be regarded merely as a suggestion of actinomycosis and not an example of it.

The transmission of the ray fungus, *Actinomyces*, by means of straw, chaff, the beards of rye, wheat and other grasses through decayed teeth to the alveolae, through the gums to the bone, through the tonsils to the pharynx and trachea and to other parts of the respiratory tract, is all well established and known through the researches of many investigators.[1] I have seen sections from the tonsil

[1] M. Schlegel, 1913. Aktinomykose. Handbuch der pathogenen Mikroorganismen (Kolle und Wassermann), 2nd edition, V 301. A later account based on Schlegel's summary is in V. A. Moore, 1916. The Pathology and Differential Diagnosis of Infectious Diseases of Animals, p. 255.

of a pig in which were embedded fragments of straw fringed with an abundant growth of *Actinomyces*, similar to figures in Kolle and Wassermann's Handbuch.

Cattle are especially susceptible to the disease and there has been a great amount of discussion as to the influence of this disease on the flesh of animals in respect to its use as food. Other animals are afflicted, however, and examples have been seen in bears, deer, dogs, cats, horses, swine, sheep, elephant and man. Cases of human actinomycoses are not uncommon, sometimes even taking the form of a suppurative "lump-jaw." The disease is pretty generally distributed throughout the world and recognizable lesions on domestic animals are not uncommon. The disease not only afflicts the respiratory and oral passages but also the skin, subcutaneous tissues, lymph glands and adjoining structures. The disease is seldom fatal so its influence in the extinction of ancient races was of very little value.

So far as I can learn no example of actinomycosis has ever been reported in the rhinoceros. The present instance then, if properly interpreted, is the first recognition of the occurrence of this disease in the Rhinocerotidae. The jaw bearing the pathological lesion was loaned me for study by Mr. Harold Cook, of Agate, Nebraska, and was collected by him in the Snake Creek, Pliocene, beds of that state. A general discussion of the nature of these deposits is given in Chapter V, under the heading "Spondylitis deformans in a Pliocene Camel." The specimen is that of an adult rhinoceros of the genus *Aphelops*, an extinct group which ranges from the Middle Miocene to the Pliocene.[2] The specimen presents the right mandibular ramus complete and a portion of the left ramus (Figure 24) for the distance of the anterior diastema in which the actinomycotic osteitis is evident. Both incisor teeth are lost, and into the alveolus of the left one, which is greatly carious, has penetrated a necrotic sinus from the actinomycotic lesion.

The tumor-like mass on the whole resembles a lesion of "lump-jaw" in a modern cow with which it has been compared. The interior of the tumor mass has a mealy appearance as if all or nearly all traces of osseous structure were lost and from this central mass, which in life was filled with pus, radiate out in an irregular manner several necrotic passages through which a chronic discharge of infective material has passed. The surface of the bone, greatly swollen, is very rough with low blunt osteophytes scattered irregularly over its surface. I assume

[2] An excellent account of the fossil forms is given by H. F. Osborn, 1898. The extinct Rhinoceroses. Memoirs Amer. Mus. Natl. Hist., I, no. 3.

ıat most of the tumor mass is lost, for the actinomycotic osteitis ırmed a plane of weakness through which a prefossilization fracture ccurred separating the posterior portion of the left ramus from the re- ıainder of the jaw, so all we have left is the anterior part of the lump. 'he fistulae were doubtless discharging pus at the time of death of the ıimal since there is little evidence of healing. There is no reason to as- ıme that during the life of the animal, a million years ago, the lesions ıd an appearance at all different from modern cases of "lump-jaw."

Of course it must be clearly recognized that the assignment of this sion to actinomycosis is purely on the basis of a comparison, exter- ally, with modern lesions of that type. The fossil rhinoceros presents a sion on the mandible, a common place for the occurrence of ac- nomycosis in modern times, and the lesion has all the external ap- earances of an actinomycotic osteitis but no search for fossil ray ıngi has been made from the fossil jaw. Such a search would be futile s I have assured myself from a microscopic examination of scores of ther fossil lesions. Bacteria would doubtless be found in the canal- uli but these would be of no significance in diagnosing the pathology. Iycelia *might* occur in the remaining lacunae but I have not thought worth while to search for them, for even if found they would not be of ositive significance.

HYPEROSTOSES OR PACHYOSTOSES (GIANTISM) IN ANCIENT ANIMALS

The type of pathological changes referred to under this heading not due to infection, irritation, fracture or any of general phases of yperplastic outgrowths referred to elsewhere but is of the nature f general enlargement of parts or of the entire skeleton, similar to ıose osseous enlargements seen in cases of human giantism. In view f the suggested relationships existing between such conditions and isorders of the pituitary body, it will be of interest to cite here what we now of such conditions in earlier animals.

I have not seen any example of such hyperostoses, nor do I know of ny such having been described among American fossil vertebrates, but ıe evidence presented here is based on discussions in the foreign litera- ıre and chiefly the studies of Abel (1912), Volz (1902), Brandt and teindachner (1859) and other European writers. It was Abel, the istinguished paleontologist of Vienna, who proposed the comparative erm *pachyostoses* for such conditions. These have already (Plate X, b) een briefly referred to in Chapter I but since Abel's (1912) account is

the most complete survey of the subject I have though best to quote his exact words in regard to the matter:

Fossile Knochen zeigen sehr häufig jene Veränderung der Form and Struktur die als *Pachyostose* oder *Hyperostose* bezeichnet zu werden pflegt. Diese Veränderungen sind bei einzelnen Gruppen von functioneller Bedeutung, wo es sich um die Ausbildung eines inneren Körperpanzers als Schutz gegen die Brandung etc handelt.

Unter den lebenden Sirenen besitzt nur der Dugong pachyostotische Knochen. Bei den fossilen Halicoriden ist aber die Pachyostose des Skelettes weit stärker gewesen und hat fast alle Knochen ergriffen. Während bei der primitiven Sirene Eotherium aegyptiacum Owen aus der mitteleozänen unteren Mokattamstufe Aegyptens nur der vordere Teil des Thorax und die vorderen Rippen neben anderen Skelettelementen (Schulterblatt, Schädel, Unterkiefer) pachyostotisch verändert sind, hat die Pachyostose bei der jüngeren Eosiren libyca Andrews bereits auf die hinteren Wirbel und die hinteren Rippen übergegriffen und schreitet bei Halitherium und Mataxytherium in Oligozän und Miozän noch weiter fort, um bei dem pliozänen Felsinotherium das Maximum zu erreichen.

Dieselbe Erscheinung zeigen die als Pachycanthus Suessi Brandt beschriebenen Bartenwale der sarmatischen Stufe des Wiener Beckens. Die ersten Anfänge der Wirbel- und Rippenpachyostose sind schon an Cototherien der Leithakalkbildungen zu beobachten, wie u.a. ein Wirbel im Wiener Hofmuseum zeigt. Auch hier handelt es sich um eine Knochenerkrankung, die später von funktioneller Bedeutung geworden ist.

Ebenso sind auch die Knochen der Sauropterygier pachyostotisch verändert; schon Proneusticosaurus zeigt diese Erscheinung sehr deutlich und zwar besitzen die Wirbel dieses Sauropterygiers eine auffallende Aehnlichkeit mit den Wirbel von Pachycanthus infolge der eigentümlich birnförmig angeschwollenen Wirbelfortsätze (Neuropophysen und Diapophysen). Auch bei vereinzelten fossilen Fischen, z.B. bei Caranx carangopsis aus der sarmatischen Stufe des Wiener Beckens sind pachyostotische Knochenveränderungen beobachtet worden.

The sacral vertebra referred to by Abel, as belonging to the Sauropterygian, *Proneusticosaurus silesiacus* Volz, from the Middle Trias is shown in Plate X, b.

OSTEOMALACIA IN AN EOCENE CARNIVORE

A diagnosis of a nutritional disturbance, such as osteomalacia, as the cause of the pathology of the limb bones of the early carnivore must be regarded as extremely uncertain. The diagnosis in this case means that the lesions look more like those seen in examples of modern osteomalacia than other lesions I have seen. *Limnocyon potens*, the primitive, creodont carnivore from the Washakie Eocene exhibits, on a skeleton preserved in the American Museum of Natural History, in the lower part of the tibia and fibula, as well as the tibio-tarsal joint and certain of the tarsal bones, carious hyperplastic lesions. The shafts of the limb bones are not involved, and the femur, measuring less than five inches in length, is normal. The tibio-tarsal joint and the

articular surfaces of the calcaneum and astragulus are invaded by arthritic lesions (Plate LI). There is considerable hyperostosis evident in an examination of the entire bones, an enlargement to nearly twice the natural size. The relation of this form of pathology to trauma must be kept in mind.

TRAUMATIC LESIONS AND OTHER PATHOLOGY OF THE PLEISTOCENE MAMMALS

The remains from the Cumberland cave deposits of Maryland represent a considerable mammalian fauna, not the least interesting of which is an American cave bear of two species.[3] A right femur of one of these bears, No. 8905, U. S. N. M., on the lower posterior surface of the bone shows a wide area of carious roughening with low, blunt osteophytes (Plate LV). The bone is somewhat hypertrophied and doubtless the lesions indicate a severe trauma.

A mastoid of a peccary, *Platygonus*, from the same deposits, shows a marked osteoperiostitis. The bone has a superficial carious roughening as if a superficial flesh wound had become infected. There are no evidences of necrotic sinuses.

The feet of the large South American edentates, known as ground sloths, often show osteophytes on foot bones.

A metatarsal of a giant wolf, *Aenocyon dirus* Leidy, (Plate LIV), from the Pleistocene, Rancho la Brea beds of southern California, shows evidence of a healed fracture of the middle of the bone with repair and ensuing callus and descending osteophytes. Section (Plate LIV, f.) through the bone shows some hyperostosis.

A metatarsal of a huge saber-tooth cat, *Smilodon* (Plate LIV) from the same beds shows on one surface a sharp exostosis, doubtless due to an infection of a tendon sheath, or some similar irritation. Another similar bone (Plate LIV) exhibits on the lower end of the bone considerable carious roughening and hyperostosis.

Many phalangeal bones of the giant wolf, *Aenocyon dirus* Leidy, exhibit evidences of rheumatic disturbances, and in one (Plate LIII, d and g) there are extensive necrotic sinuses, as of osteomyelitis, or some similar long-standing necrosis. Many vertebrae of *Smilodon* exhibit pathological lesions indicating a wide variety of trauma. (Fig. 25.)

Discussions of other Pleistocene lesions will be found in Chapter I.

[3] J. W. Gidley, 1913. Preliminary Report on a recently discovered Pleistocene cave Deposit near Cumberland Maryland. Proc. U. S. Natl. Mus., xlvi, 93–102.

1920. Pleistocene peccaries from the Cumberland Cave Deposits. Proc. U. S. Natl. Mus., lvii, 651–678.

SKELETAL ANOMALIES AMONG FOSSIL VERTEBRATES

Anomalies are seldom seen among fossil vertebrates and have attracted very little attention from paleontologists. It seems rather peculiar that no specimens of Teratomata or other teratological evidences have been found among fossil vertebrates. Possibly this is to be explained by the scantiness of the recorded vertebrates as compared to the numbers which must have lived in ancient times.

An apparent anomaly possibly to be interpreted as an anomalous vascular foramen or an aberrant nerve foramen due to a thoracic spinal nerve, is to be seen in the right scapula of *Trachodon annectens*, a Cretaceous dinosaur, the skeleton of which is mounted in the Yale University Museum. Near the posterior margin of the superior border of the blade of the scapula (Fig. c, Plate XXIX) is an elongate, elliptical hole 8 cm in length, with smooth edges, indicating possibly, that the animal received a severe injury during life and completely recovered from it before death, or it may be an anomaly. The presence in the same beds of numerous remains of armored and horned *Triceratops* suggests that there may have been an encounter between these two dinosaurs and the injury due to a horn thrust from one of the three-horned dinosaurs.

Various anomalies of the teeth, extremities and vertebrae have been discussed by Schlosser who finds that in the Pleistocene cave bears of the caves of the Kaiserthal near Kufstein, Austria, anomalies exist oftener in the vertebrae than in the teeth or extremities. The anomalies described by Schlosser were, for the most part, slight variations from the normal and do not partake of the nature of teratological[4] variations.

[4] T. Popescu-Voitesti, 1908. Abnormale Erscheinungen bei Nummuliten. Beitrag. Pal. u. Geol. Oesterr.-Ungarn. u.d. Orients, xxi, 211–219.

DESCRIPTIONS OF FIGURES 23-25 AND PLATES XLVII–LVIII ILLUSTRATING CHAPTER VII

FIGURE 23

Right and left views of the mounted skeleton of the dinosaur *Camptosaurus* in the U. S. National Museum, showing in the ilium on the right side a necroti sinus, outlined in ink. The nature of the sinus is shown in Plate L, a.

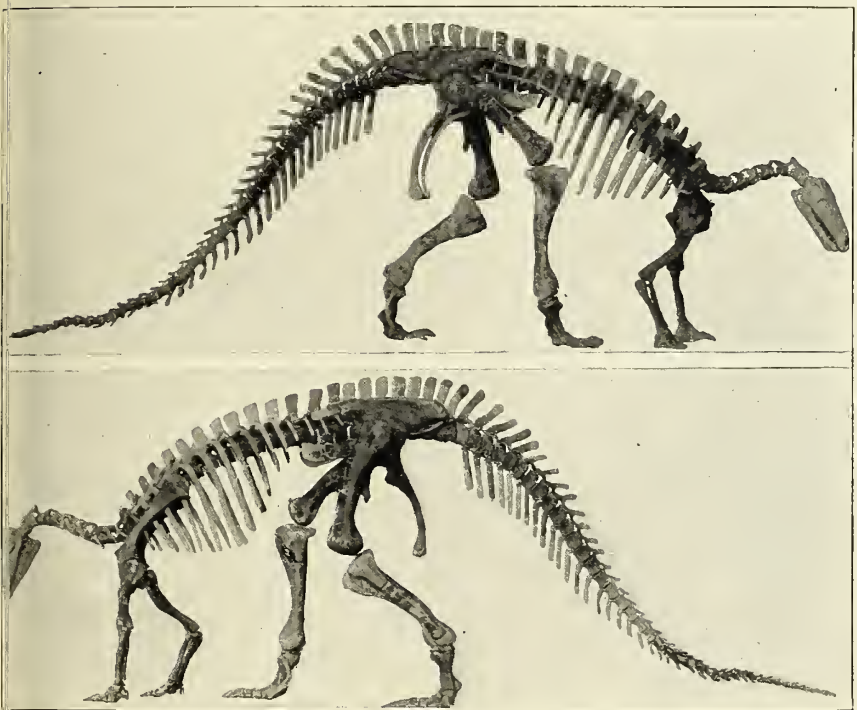


FIGURE 23

FIGURES 24-25

FIGURE 24

Right mandible of *Aphelops*, a fossil rhinoceros from the Pliocene, Snake Creek beds of western Nebraska, showing at the arrow the lesion in the left ramus which is interpreted as evidence of actinomycosis. Specimen loaned by Mr. Harold J. Cook.

FIGURE 25

Diseased lumbar vertebra of *Smilodon*. A sabre-toothed cat from the Pleistocene of the Rancho la Brea, showing evidences of an intense infection in the right apophysis. Specimen presented by Mr. E. S. Riggs.

FIGURE 24

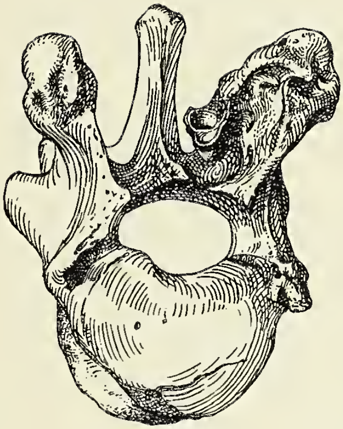


FIGURE 25

PLATE XLVII

PLATE XLVII

FAMOUS FOSSIL BEDS

a-b. Views at the Rancho la Brea asphalt beds near Los Angeles, California, whence come numerous remains of Pleistocene mammals.

a. View of one of the pools. Gas bubbles may be seen breaking the surface of the oil and water. The fossil bones are quarried from the banks of these pools.

b. Asphalt seep on the margin of a tar pool.

c. Excavating fossil skeletons of Oreodonts from the Lower Miocene Rocks of Northwestern Nebraska. There are five almost complete skeletons entombed in the block between the workers. American Museum of Natural History Expedition of 1908.

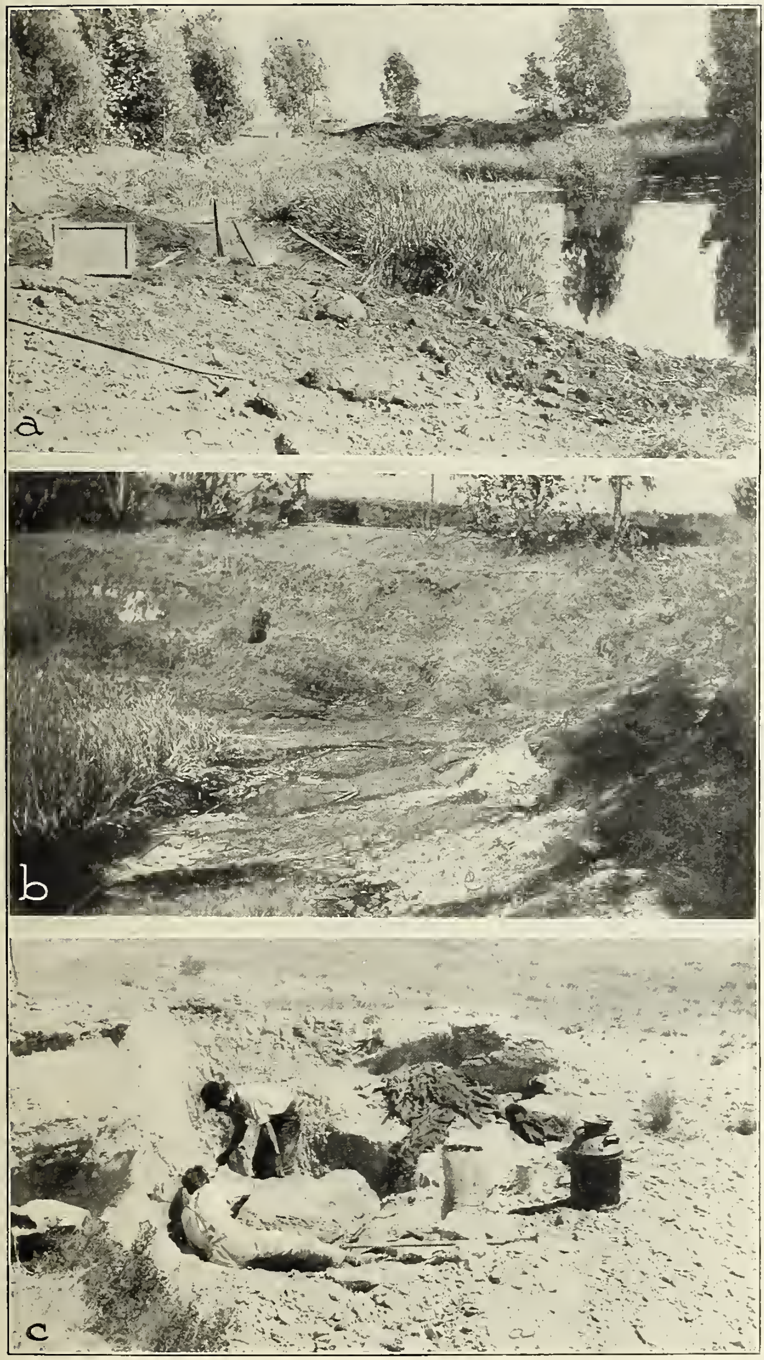


PLATE XLVII

PLATE XLVIII

PLATE XLVIII

MESOZOIC PATHOLOGY

a. Radius of a mosasaur, a large swimming reptile from the Niobrara Cretaceous chalk of western Kansas, showing at the upper pole, a huge necrotic sinus, evidence of the presence of pathogenic bacteria during the closing period of the Mesozoic The arrows indicate the plane in which the bone was cut to obtain the view shown in "b."

b. Slightly enlarged view of a median section of the diseased radius of the mosasaur shown in "a." The huge necrotic sinus was in the end of the articular surface of the bone. The darkened areas are hypertrophied bone.

c. Dorsal vertebra of a mosasaur, *Platecarpus*, from the Cretaceous of Kansas presenting on the ventral surface the unique *osteoma.*

d. Outline of a median sagittal section of the same bone showing in the shaded area the portion enlarged in Plate XL.

e. An immature, possibly embryonic, propodial, upper limb bone, of a plesiosaur, a large swimming reptile, from the Cretaceous of Kansas, showing at the arrow a pathologic exostosis. Natural size.

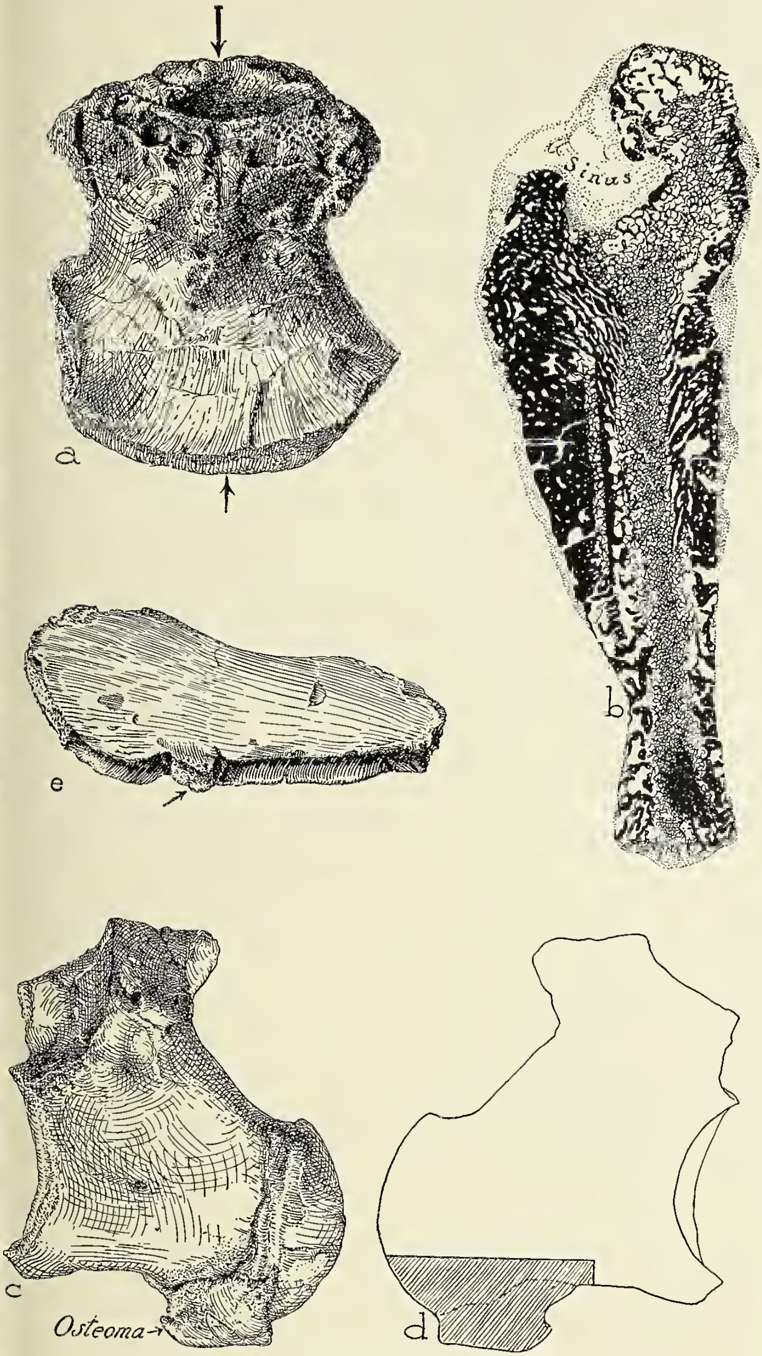


PLATE XLVIII

PLATE XLIX

PLATE XLIX

A CRETACEOUS NECROSIS

a. Sawn sagittal section of radius, taken, in plane shown by arrows in "a," Plate XLVIII. The sinus is seen to be an irregular cavity, and immediatel below this occur areas of hypertrophied bone, evident in the blackened portion o the drawing "b" Plate XLVIII. These areas lack the abundant small vascula spaces which are to be found in the normal bone of this reptile. Enlarged.

b. Arm bone, radius, of a swimming reptile from the Cretaceous of Kansas showing roughened area, necrotic sinus, and hypertrophy. The necrosis is possibl due to bacterial activity and was of long duration. End view.

c. Photomicrograph of pathologic exostosis on humerus of plesiosaur from th Cretaceous of Kansas. X 200. Compare Plate XLVIII, e.

PLATE XLIX

PLATE L

PLATE L

PATHOLOGY IN TWO DINOSAURS

a. The right ilium of *Camptosaurus browni,* a large dinosaur from the Cretaceous of Wyoming, showing a large necrotic sinus at "A."

The left side of the same skeleton shows a normal ilium. Specimen mounted in the U. S. National Museum at Washington.

b-c. Two views of the right scapula of *Triceratops*, a large three-horned dinosaur from the Upper Cretaceous of Wyoming. The inner surface, on which this horn-like projection appears, should be perfectly smooth, for this is the visceral surface which slides over the ribs. The lesion doubtless caused considerable irritation of the pleura. The specimen is some three feet in length. Preserved in the U. S. National Museum. Courtesy of Mr. Charles Gilmore.

Plate L

PLATE LI

PLATE LI

EOCENE OSTEOMALACIA

Lower ends of the tibia and fibula, with tarsal bones, of *Limnocyon potens*, an early carnivore, from the Washakie Eocene, nearly 3,000,000 years old. These bones show considerable exostoses and suggest, from their appearance, the lesions seen in Osteomalacia or other nutritional disturbances. Specimens in the American Museum of Natural History. Courtesy of Dr. W. D. Matthew.

PLATE LI

PLATE LII

PLATE LII

ANCIENT CHRONIC INFECTIONS

a. A drawing of the exostosis on the visceral surface of the scapula shown in Plate L, b and c. *Triceratops*.

b. A human femur, recent, showing an exostosis similar in its general external appearances to that shown in "a." The exostosis on the femur was buried in muscles, while that on the dinosaur scapula was doubtless a source of considerable irritation.

c. A phalange of an extinct mammal, known as *Merycochoerus rusticus* Leidy, a pig-like ruminant from the Oligocene of Nebraska, showing extensive carious roughening. (After Leidy.)

d. Toe bone of *Diceratherium cooki*, a rhinoceros from the Agate Springs Quarry, Lower Miocene, Niobrara Valley, Sioux County, Nebraska, showing exostoses of osteoperiostitis. Collected and loaned by Mr. Harold J. Cook.

e. Pathologic caudal vertebrae of a large mammal from the Pliocene of Nebraska. The nature of the pathology is uncertain. While it has some resemblances to spondylitis deformans it seems not to conform to other lesions of that nature. Collected and loaned by Mr. Harold J. Cook.

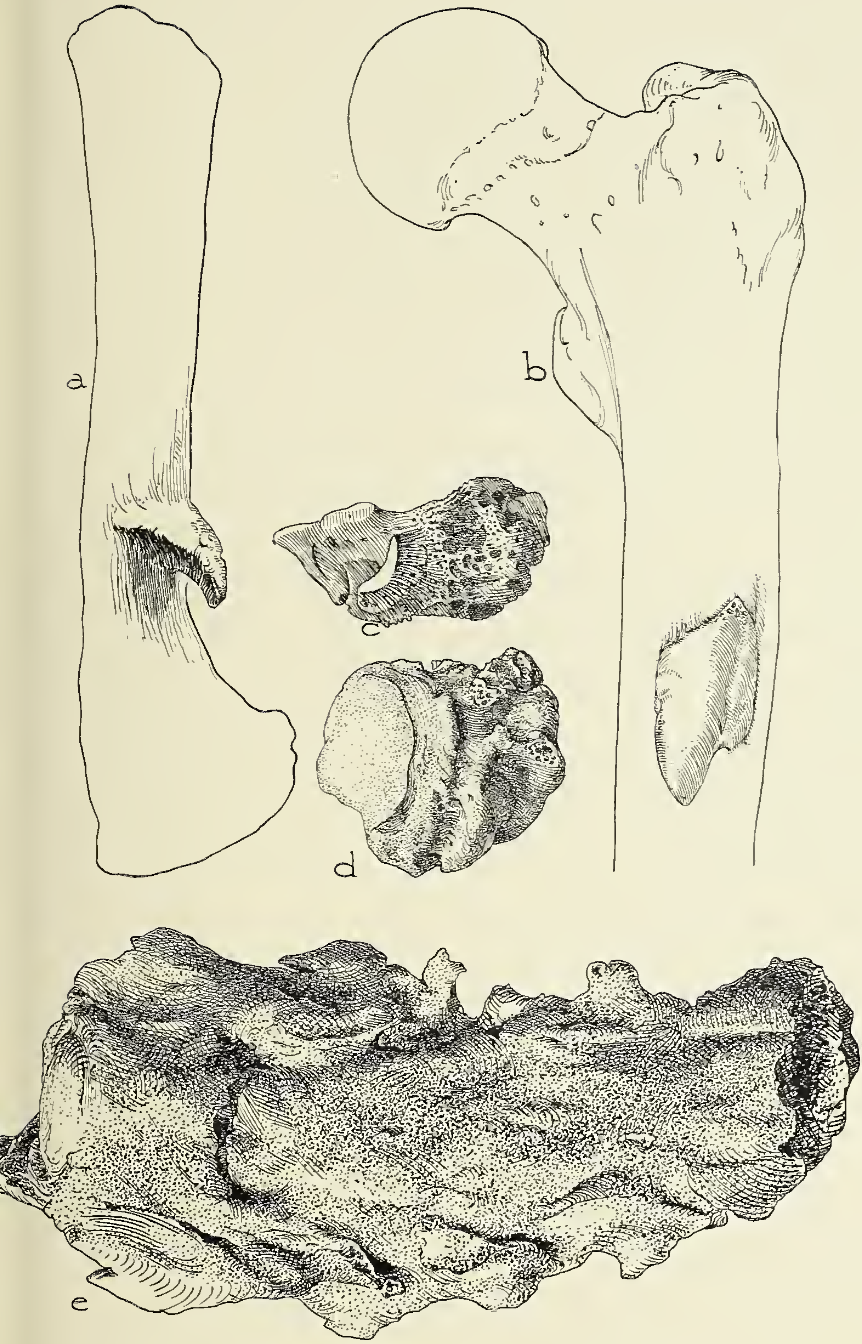


Plate LII

PLATE LIII

PLATE LIII

PATHOLOGY IN FOSSIL MAMMALS

a. A small area of one of the fossiliferous asphalt beds at Rancho la Brea ir process of excavation, showing the skeletal remains before they had been completel; uncovered. In this picture there may be seen the under side of the lower jaw of ε horse, considerable parts of the skulls of four saber-tooth cats, four large wolf skulls two coyote skulls, and many other skeletal parts only imperfectly preserved. Th figure serves to show how crowded the area must have been in early Pleistocen times and how frequent traumatic lesions may have been produced. (After Mer riam.)

b. Right radius of *Daphaenus felinus*, a large dog from the Oligocene of Ne braska, 2,500,000 years old, showing on the lower end a large exostosis, which i matched on the other radius by a duplicate lesion. The lesions are slightly unequal the left being almost twice as long as the right. Both of the tumor-like growths enc in four or five osteophytes. *Daphaenodon*, a related dog, has the radii smootl without any evidences of pathology. Skeletons of these two interesting ancien dogs are on exhibition at the Carnegie Museum, Pittsburgh.

c. End view of radius showing ventral appearance of tumor. (After Hatcher.

d. and *g*. Dorsal (d) and end (g) views of phalange of a giant wolf from th Pleistocene of California showing erosions of chronic osteomyelitis.

e. and *f*. Lateral view (e) and section (f) of a fractured metatarsal of a wol from the Pleistocene of California.

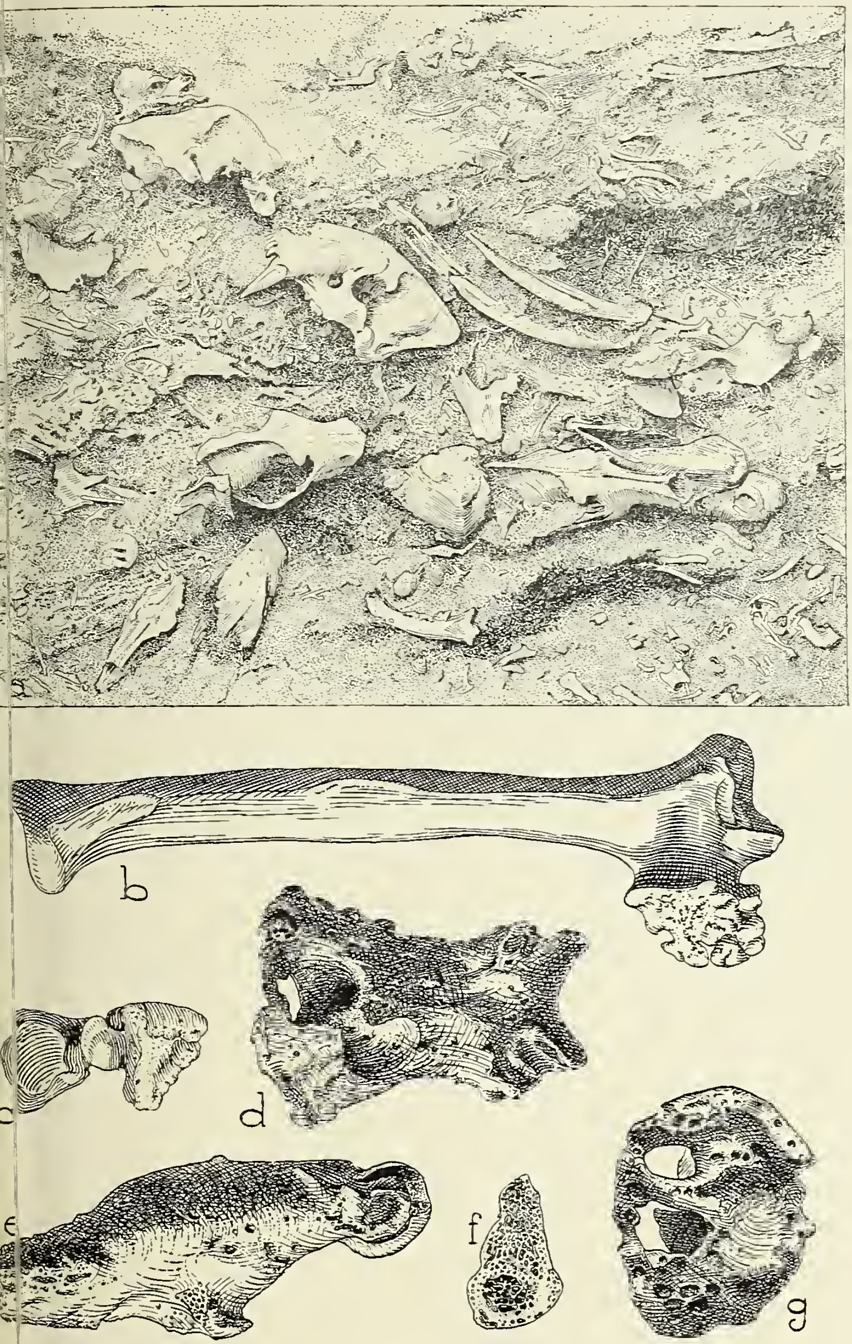


PLATE LIII

PLATE LIV

PLATE LIV

PLEISTOCENE PATHOLOGY

a. End view of phalange of wolf showing necrosis.

b. Photomicrograph of a section cut through the exostosis shown in the middle upper figure of "c." X 70.

c. Pathologic foot bones from the Rancho la Brea of California. From left to right they are:

Upper row: Metatarsal of a giant wolf, *Aenocyon dirus*, showing a fracture of the middle of the bone with repair. The ensuing callus and hypertrophied parts are roughened indicating an infection. The same bone is shown in Plate LIII, e.

Metatarsal of a saber-tooth cat, *Smilodon*, showing on the upper right hand surface a sharp exostosis doubtless due to an injury of a tendon sheath.

Another metatarsal of same animal showing on the lower end considerable carious roughening.

Lower row: Various pathologic phalanges of giant wolf.

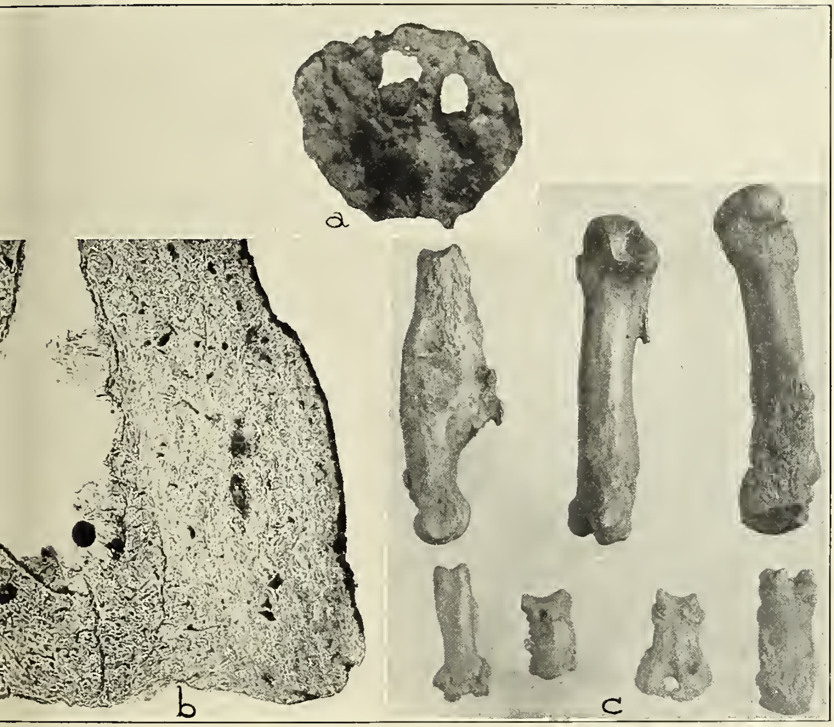


Plate LIV

PLATE LV

PLATE LV

PLEISTOCENE OSTEOPERIOSTITIS

Right. Mastoid of *Platygonus* showing osteoperiostitis (not well shown in photo) from Cumberland Cave, Maryland shows no evidences of necrotic sinuses but carious roughenings as if a superficial flesh wound had become infected.

Left. Right femur of a cave-bear from Cumberland Cave. No arthritis. No. 8905 U. S. National Museum.

Lower posterior surface of bone shows a wide area of carious roughening with low blunt osteophytes.

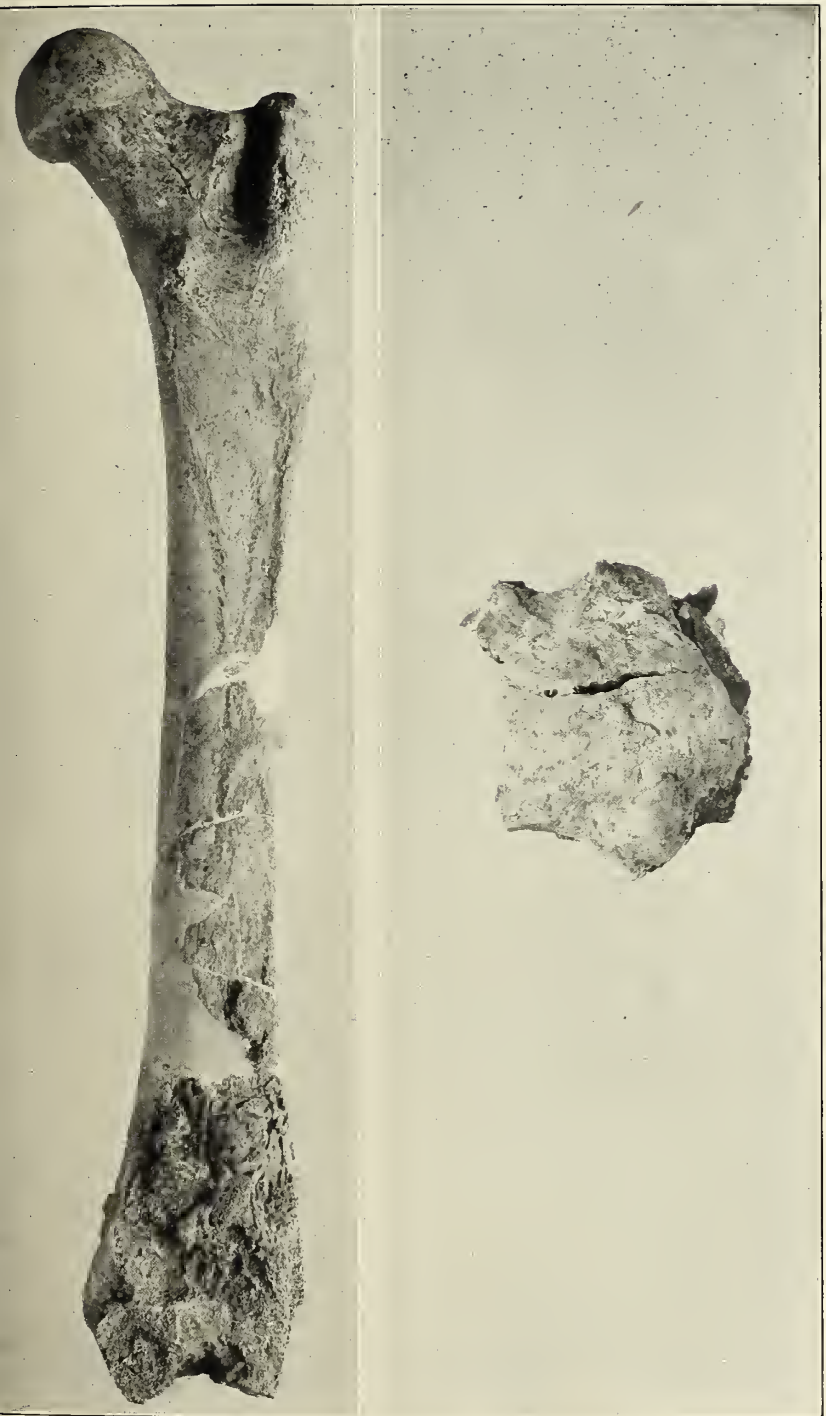


PLATE LV

PLATE LVI

PLATE LVI

PATHOLOGY OF AMERICAN BISON

Upper figure. Lesions of chronic osteomyelitis, doubtless resulting from a compound fracture, seen on the under surface of a metacarpal of an American Bison from the plains of Kansas.

Lower figure. Lesions of arthritis deformans seen in and around the head of the humerus of an American Bison from the plains of Kansas.

PLATE LVI

PLATE LVII

PLATE LVII

PATHOLOGY IN THE AMERICAN BISON

Left. Conjoined vertebral spines of an American Bison.

Right. Chronic osteomyelitis developed in the knee of a bison due to a bullet wound. Posterior view. The bullet was still in the wound.

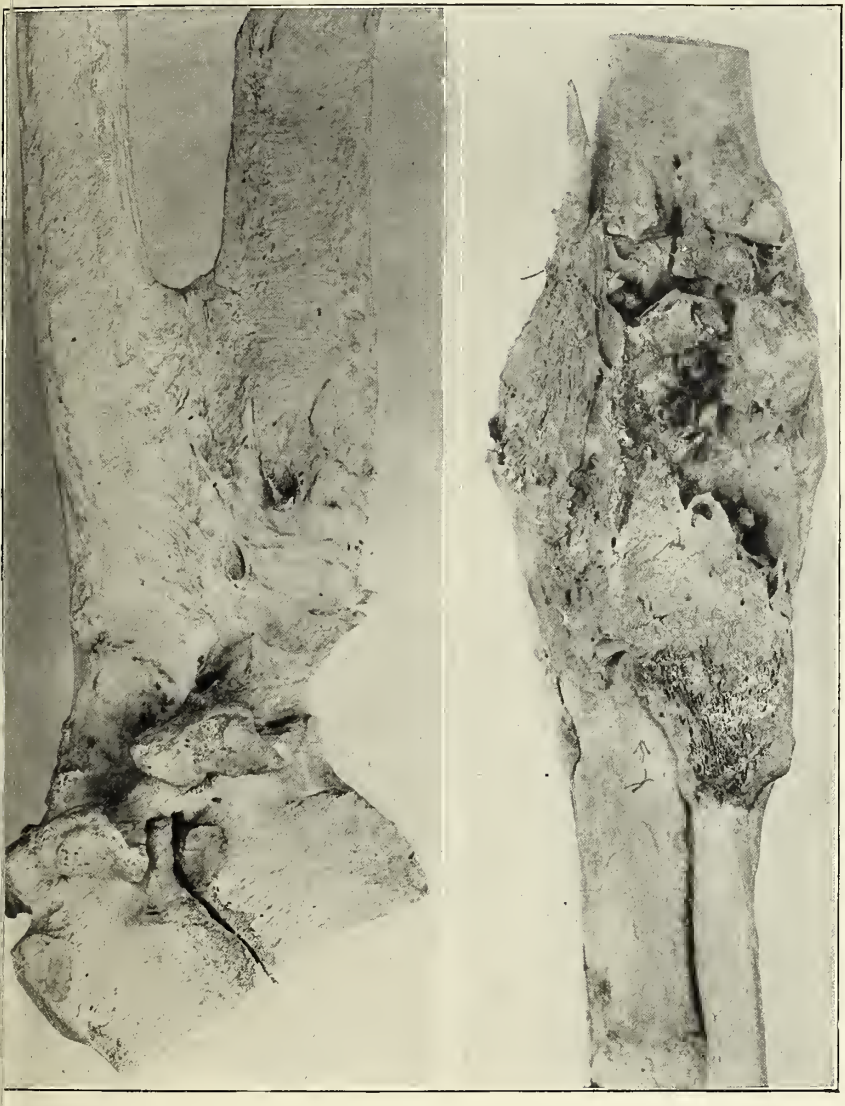


Plate LVII

PLATE LVIII

PLATE LVIII

CHRONIC INFECTIONS

a. Lumbar vertebrae of a Pliocene camel, showing lesions of spondylitis deformans at the arrows. The two bones are firmly conjoined. Reduced.

b. Leg bone of a three-toed horse showing at the upper end, slight lesions of a periarthritic nature.

c. Toe bone of a three-toed horse showing osteohypertrophy and low, blunt osteophytes.

d. Toe bone of a camel, showing arthritic lesions.

All specimens collected in the Pliocene, Snake Creek beds of western Nebraska by Mr. Harold J. Cook, and loaned by him.

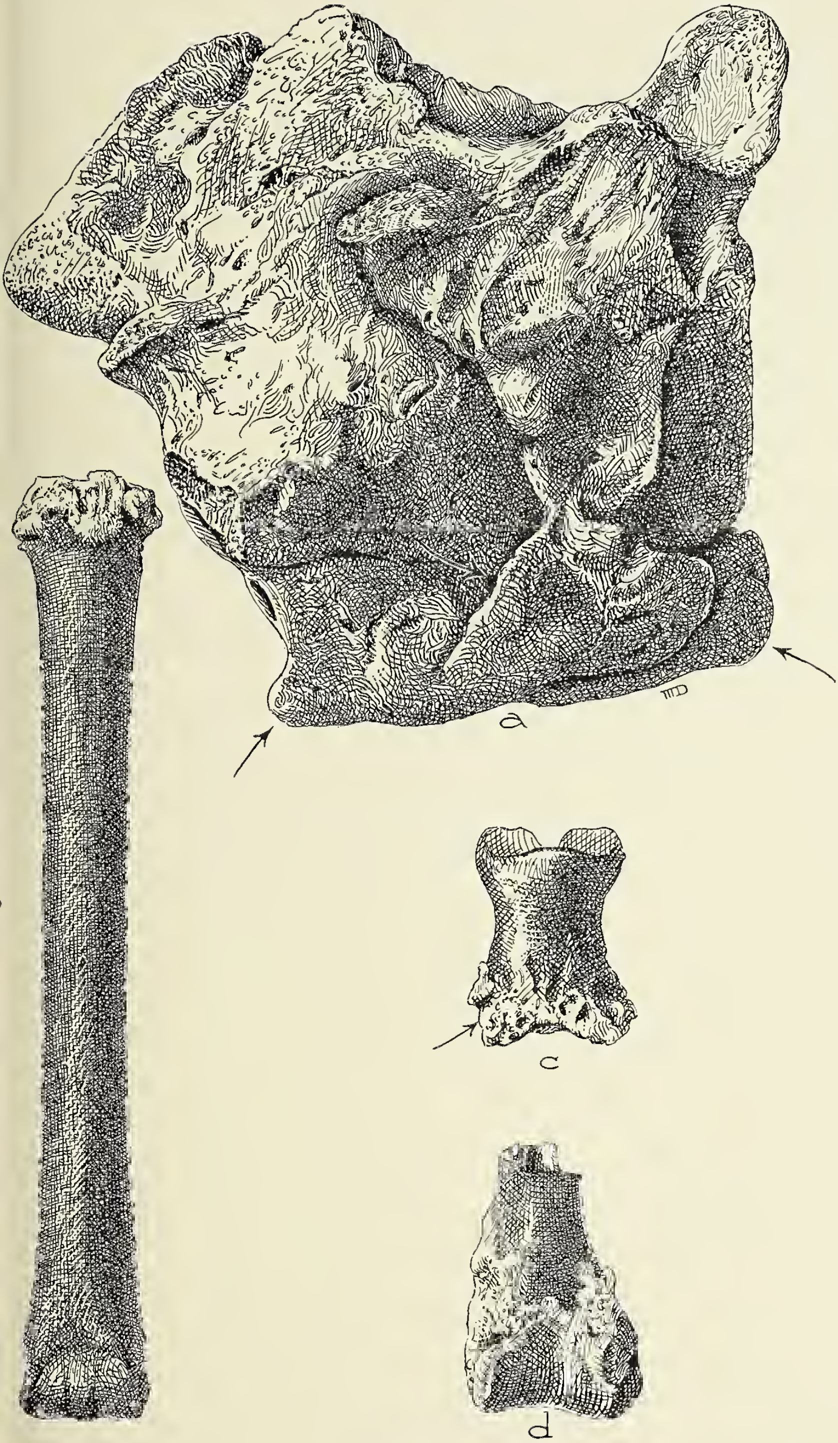


Plate LVIII

CHAPTER VIII

PARASITISM AMONG FOSSIL ANIMALS

The origin of parasitism. Symbiosis among fossil animals. Parasitism of Carboniferous inoids. Theoretical aspects of Paleopathology. A case of Pleistocene parasitism.

THE ORIGIN OF PARASITISM

Parasitism began, doubtless, when there were forms developed ıpable of living at the expense of another. It has been suggested that ırasitism and consequently disease began in the Proterozoic. This ea is based on the theoretical assumption of the infection of early osts by sporozoans, a supposition which can be neither denied nor firmed on definite evidence. This interesting possibility I have shown a diagram on a later page and it must be considered as a possibility in scussing the origin of parasitism. It is true that most parasites leave tle or no impress on the hard parts, hence the geological record is very complete in this respect and we shall probably never know the actual ginnings of parasitism. The evidences of dependent life, symbiosis ıd parasitism, presenting themselves to the paleontologists must be iefly of marine origin, since very little is known of early fresh water rms, adapted to a single host; they must, moreover, be simple in their pression and may be easily misunderstood. The ancient faunas show at these associations of dependence began far back in the history life.

There have been assembled by Dr. John M. Clarke (1921) materials om the older faunas of geological history which illustrate the beginngs of dependent life, thus attacking the problem in a practical way. e has described in an essay, "The Beginnings of Dependent Life," amples which form the basis for our present knowledge of the beginngs of symbiotic and parasitic conditions. He says:

> So far as our facts go there are but few evidences of true parasitic conditions the Paleozoic faunas. The oldest and clearest is the well known case of the coalin of the limpetlike snail, Platyceras, and the crinoids. The snail settles down at early age on the dome of the crinoid placing the aperture of the shell over the al vent of its host and remains attached for an indefinite period of its subsequent e.
>
> It is clear that the snail depends for its food on the waste from the crinoid and e fact that it remains attached for a very considerable period of its existence is own by specimens of the crinoid dome bearing successive scars made by the

enlarging growth of the mouth of the snail shell. Though this is the most extreme expression of ancient parasitism known to us, it was evidently of a very elastic kind and by no means affected all individuals of this genus of shells. This combination makes its first appearance in the early Devonic and seems to have become intensified in the great crinoid plantations of the early Carbonic but in either formation the examples of the actual dependent combination are in very slender proportion to the number of individuals of either snail or crinoid. Some of the snails acquired this habit of parasitic dependence, others evidently did not. Apparently it was in some measure an individual adjustment. Yet the more general dependence of this snail, Platyceras, on the crinoids is indicated by the fact that quite generally Paleozoic strata carrying an abundance of the one also abound in the other.

Time has not extinguished this affiliation, for the existing seas afford occasional evidences of similar relation between the limpets and the crinoids. Our material seems to throw some light on the inception of this dependent habit. A crinoid, Glyptocrinus, from the Upper Siluric is occasionally found inclosing in its arms a holostomatous snail, Cyclonema, not attached to the dome, for the shell had not the limpet habit of attachment, but lying free in such attitude as to get the full advantage of the crinoid's waste.

True dependence is also indicated by a similar association between the crinoids of the Carbonic rocks and the starfish Onychaster (Figure 26). The starfish adjusts itself, mouth downward, over the anal aperture of the crinoid. Our specimens showing this condition have been caught in this act of feeding. The flexible character of the starfish made the attachment easily subject to change. This association too is one that time has not cured.

SYMBIOSIS AMONG FOSSIL ANIMALS

Commensalism and symbiosis are the natural precursors of parasitism, and these associations became established more abundantly and at an earlier date than parasitism. Clarke (1921) has established a number of examples and has illustrated a variety of Paleozoic symbiotic associations.

The coexistence of the tubicolous worms with the corals became established at a very early stage in the earth's history and in the Devonic coral reef the habit had already become widespread and varied. Probably less frequent in Siluric times the oldest known examples indicate an elementary expression of commensalism.

A typical case of symbiosis, involving the association of a hydractinian and a hermit crab, has been described from the Eocene of Egypt, and has been called "Kerunia" after the place where it was found, Birket-el-Kerun. Fraas[1] described similar forms from the Fiji Islands. While the fossil Kerunias consists of hydractinians which have grown around small snail shells, the recent ones have been formed upon a nucleus of serpulid shells. In the fossils the gastropod shells which

[1] E. Fraas, 1911—Eine rezente Kerunia-Bildung. Verhandl. k.k. zool. botan. Ges. in Wien, lxi, 70.

had been overgrown by hydractinians had later served as dwelling places for hermit crabs.

The relation of the myzostomid worms to modern crinoids is often of a parasitic nature.

The colouration of the myzostomids and their relation to that of their hosts is not very exact, since blackish, yellow and white myzostomids occur just as frequently on red comatulids as blood-red species on variegated comatulids, though on the whole the myzostomids show a great colour resemblance to their hosts.[2]

PARASITISM OF CARBONIFEROUS CRINOIDS

Robert Etheridge (1880) was the student who first recognized the nature of the swollen stems of fossil Carboniferous crinoids although he was unable to determine the nature of the parasite. He found on opening one of the enlargements that a fossilized worm was evident as a piece of black matrix reposing against the further wall of the cavity. Graff (1885) was able to confirm the findings of Etheridge and recognized in the carbonized remains the fossilized integument of a myzostomid. Graff remarks:

> All deformities on fossil crinoids due to myzostomids belong to two categories of arm enlargements as represented among recent species. All fossil myzostomic deformities occur on the stems of crinoids, where the lesions are of many kinds. Many of the described cases of deformity of the stem are due to accretions of corals, bryozoans and brachiopods, but there are numerous authentic cases of stem enlargement which have involved two or more arms.

Graff reviewed the literature and referred to numerous species of crinoids which showed swollen stems, some of the species having been based on the tumors, which had been mistaken for calyces. Graff compared very carefully his results with the swollen crinoid stems described in the reports of the Challenger exploring Expedition, where the infecting forms were known to be myzostomids.

Swollen stems of crinoids are often seen by paleontologists, in Europe and America, but few have recognized their parasitic nature.

The specimens suggesting parasitism vary from half an inch to four inches in maximum diameter, the plates of the stem being greatly enlarged. The columnars are often spread out to four or five times their normal diameter, the individual plates not being separated. The enlargements are often mere bulgings of the stem (Plate LIX), and

[2] F. A. Potts: The Fauna associated with the Crinoids of a Tropical Reef; with especial reference to its colour variations. Papers from the Dept. of Marine Biology of the Carnegie Inst. Wash., viii, 93, 1915.

again they take the form of large tumors, tapering at each end to join the normal stem. Graff found the parasite located at the point of greatest enlargement.

Under the heading "*Symbiosis in the worms and crinoids*" Clarke (1921) says regarding these lesions:

> The data for such association are not abundant. *Myzostomum*, a wormlike creature, believed to be an annelid, is parasitic on living crinoids where its species (Compare Plate LIX, c) cause galls or swellings by the overgrowth of the calcareous substance. On the columns of Paleozoic crinoids small gall-like protuberances are occasionally found, with a central perforation, and several authors have ascribed these to the *Myzostomum*. These Myzostomid galls (Myzostomites) have been recorded from rocks as early as the Upper Ordovician, but we must confess to know very little about them, and some of the pittings and depressions on crinoid columns which have been thought to be the inner cavities of Myzostomid cysts are doubtless of other origin. Perhaps the best proof that these galls have been made by infesting worms is afforded by the specimen here figured (Clarke's figure 47) from the Hamilton shales of the Devonian.

It should be noted here that Bassler has described objects of a similar nature, and has interpreted them as due to the geodization (Plate LIX, b) of the portion of stem. Possibly, however, some of the enlargements represent parasitism. Graff's example seems to be beyond question. If these are parasitic tumors they are among *the oldest known pathologic lesions* in *geological history*.

I have found no other indications of parasitism among fossil animals, though doubtless this factor played an important rôle in the life history and natural selection of many extinct species.

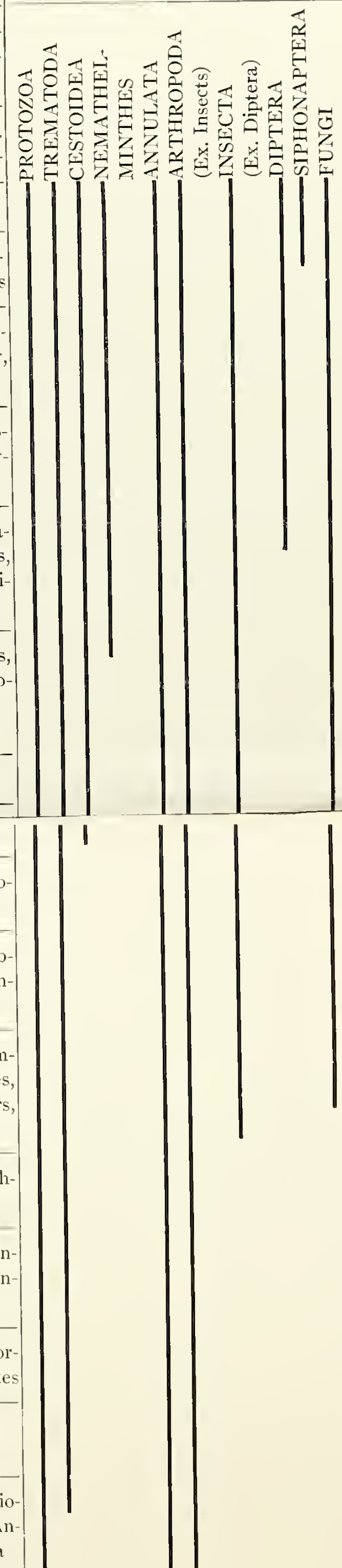
There are a number of instances showing a symbiotic relation between the fossil hexactinellid sponges of the family Dictyospongidae and worm tubes attached to the inner wall of the cloaca of the sponge. Associations of the sponges and annelids are also known. The associations of corals and barnacles are known from the Silurian and Devonian. An association of crinoids and cystids with gastropods, already referred to, is doubtless an instance of genuinely dependent parasitism where an attached organism relies upon its host for its nutriment and existence. Keyes[3] has recorded a long list of these parasitic associations and especially indicates the effect of this condition in modifying the aperture of the gastropod.

Examples of pseudoparasitism are indicated by the boring forms on dead shells, material which forms a large part of the fossils studied by the paleontologist. These boring bodies infesting the dead shells

[3] C. R. Keyes. Synopsis of American Carbonic Calyptraeidae. Acad. Nat. Sci. Phila. Proc., 1890, p. 150.

Eras	Epochs	Dominant Life
PSYCHOZOIC	Holocene (Recent alluvial)	Age of Man. Modern faunas and floras
CENOZOIC	Pleistocene or Ice Age	Great Mammals. Neolithic Man, Paleolithic Man, Pithecanthropus
	Pliocene	Anthropoids, Horses, Cats, Elephants
	Miocene	Anthropoids, Horses, Camels, Deer, Cats, Oreodonts
	Oligocene	Ancient Pigs, Rodents, Camels, Horses, Canids
	Eocene	Early Horses, Tapirs, Insectivores, Lemuroids, Carnivores
MESOZOIC	Cretaceous	Small Mammals, Birds, Giant Reptiles, Bony Fishes
	Comanchean	Reptiles, Fishes
		Fishes
	Triassic	Reptiles, Amphibians, Fishes
PALEOZOIC	Permian	Reptiles, Amphibians, Fishes, Insects
	Pennsylvanian	Small Reptiles, Amphibians, Fishes, Insects, Spiders, Crinoids
	Mississippian	Amphibians? Fishes, Ammonites
	Devonian	Armored Fishes, Insects, Shelled Invertebrates
	Silurian	Early Fishes, Scorpions, Invertebrates
	Ordovician	Trilobites, Nautilids, Molluscs
	Cambrian	Trilobites, Brachiopods, Molluscs, Annulates, Protozoa
PROTEROZOIC		Worms, Radiolaria, Bacteria
ARCHEOZOIC		No life known

Parasitic Causes of Disease



are likely to be either minute algae or fungi, or sponges in general producing similar effects to the living *Cliona* or *Vioa.* The total amount of deterioration and disintegration of skeletons caused by these minute organisms was doubtless great even in Paleozoic times. Boring pelycopods were not unknown in the early Paleozoic, and have been freely described in Mesozoic faunas and boring insects in the woods of the Tertiary.

Among the ants of the Baltic amber there is one specimen of *Lasius schiefferdeckeri* Mayr, with a mite attached to its leg in exactly the same manner as we find mites attached to ants and to other insects at the present time. This is the only known case, according to Dr. W. M. Wheeler, of actual parasitism in these Oligocene insects.

The present distribution of the two species of hookworms which parasitize man, *Ancylostoma duodenale* and *Necator americanus*, indicates[4] a prior occurrence of these species in the anthropoid ancestors of the human race. The dispersal, as seen from present evidences, was evidently from an Eurasiatic race of pre-humans, indicated by the *Pithecanthropus* of Java, may have been in conjunction with the development of this race of beings from which man of the Oriental and Ethiopian regions sprung. The fossil gibbon, *Proliopithecus*, emerging from Holoarctic Africa may have been not only the parent form of man, gibbon, chimpanzee, gorilla and orang-outang, but he may have harbored the parent form from which have arisen the different hookworm species which at the present day infest man and anthropoids. This suggestion is supported by the zoological data of the mammals of Asia. The geography of disease will thus need to be rewritten to include the facts and suggestions of Paleopathology, and especially the deductions based on the dispersal of the host of disease-producing parasites.

THEORETICAL ASPECTS OF PALEOPATHOLOGY

The accompanying table is intended to show certain possible relations of parasites to early hosts. It is based on the modern hosts, as given by Castellani,[5] in which the parasites, or parasite carriers, are known to produce disease, and the antiquity of these hosts in geological time. The apparent error in the conception is that we do not know whether parasites attacked the early representatives of their modern hosts, and if they did whether the antagonism was sufficient to cause

[4] Samuel T. Darling: 1921—The Distribution of Hookworms in the Zoological Regions. Science, N.S., vol. LIII, no. 1371, 323–324.

[5] Castellani, Aldo and Chalmers, Albert J., 1913—Manual of Tropical Medicine.

		Fishes
	Triassic	Reptiles, Amphibians, Fishes
PALEOZOIC	Permian	Reptiles, Amphibians, Fishes, Insects
	Pennsylvanian	Small Reptiles, Amphibians, Fishes, Insects, Spiders, Crinoids
	Mississippian	Amphibians? Fishes, Ammonites
	Devonian	Armored Fishes, Insects, Shelled Invertebrates
	Silurian	Early Fishes, Scorpions, Invertebrates
	Ordovician	Trilobites, Nautilids, Molluscs
	Cambrian	Trilobites, Brachiopods, Molluscs, Annulates, Protozoa
PROTEROZOIC		Worms, Radiolaria, Bacteria
ARCHEOZOIC		No life known

are likely to be either minute algae or fungi, or sponges in general producing similar effects to the living *Cliona* or *Vioa*. The total amount of deterioration and disintegration of skeletons caused by these minute organisms was doubtless great even in Paleozoic times. Boring pelycopods were not unknown in the early Paleozoic, and have been freely described in Mesozoic faunas and boring insects in the woods of the Tertiary.

Among the ants of the Baltic amber there is one specimen of *Lasius schiefferdeckeri* Mayr, with a mite attached to its leg in exactly the same manner as we find mites attached to ants and to other insects at the present time. This is the only known case, according to Dr. W. M. Wheeler, of actual parasitism in these Oligocene insects.

The present distribution of the two species of hookworms which parasitize man, *Ancylostoma duodenale* and *Necator americanus*, indicates[4] a prior occurrence of these species in the anthropoid ancestors of the human race. The dispersal, as seen from present evidences, was evidently from an Eurasiatic race of pre-humans, indicated by the *Pithecanthropus* of Java, may have been in conjunction with the development of this race of beings from which man of the Oriental and Ethiopian regions sprung. The fossil gibbon, *Proliopithecus*, emerging from Holoarctic Africa may have been not only the parent form of man, gibbon, chimpanzee, gorilla and orang-outang, but he may have harbored the parent form from which have arisen the different hookworm species which at the present day infest man and anthropoids. This suggestion is supported by the zoological data of the mammals of Asia. The geography of disease will thus need to be rewritten to include the facts and suggestions of Paleopathology, and especially the deductions based on the dispersal of the host of disease-producing parasites.

THEORETICAL ASPECTS OF PALEOPATHOLOGY

The accompanying table is intended to show certain possible relations of parasites to early hosts. It is based on the modern hosts, as given by Castellani,[5] in which the parasites, or parasite carriers, are known to produce disease, and the antiquity of these hosts in geological time. The apparent error in the conception is that we do not know whether parasites attacked the early representatives of their modern hosts, and if they did whether the antagonism was sufficient to cause

[4] Samuel T. Darling: 1921—The Distribution of Hookworms in the Zoological Regions. Science, N.S., vol. LIII, no. 1371, 323–324.

[5] Castellani, Aldo and Chalmers, Albert J., 1913—Manual of Tropical Medicine.

disease. The idea was suggested by a diagram in a paper by Eccles on "Parasitism and Natural Selection" and is incorporated here. The idea is given for what it may be worth. There is very little evidence to support the conception, since parasitic reactions are most often in soft parts which are not preserved in the rocks. We do know however that parasitism began very early and doubtless there is some basis for the idea, which we hope will be filled out in future studies of this problem.

The antiquity of parasitism is suggested by the distribution of *Myxidium lieberkühni*[6] over both Europe and America dating from the time when *Lucius lucius* attained that distribution showing that it too must be an old species, and like its host have remained unmodified through a long period.

A somewhat parallel condition is found in the *Mallophaga*, the insect parasite of birds, where a very close relation exists between parasite and host.

Kellogg[7] says: "there has been no external factor at work tending to modify the parasitic species, and it exists today in its ancient form, common to the newly arisen descendants of the ancient host."

A CASE OF PLEISTOCENE PARASITISM

An interesting form of parasitism which causes malformation not uncommon among modern decapod Crustacea is a swelling of the branchial cavity due to the presence of a parasitic Isopod of the family Bopyridae. This form of parasitism has been encountered in two cases of Pleistocene fossils from the State of Washington,[8] both in the species *Branchioplax washingtoniana*, Rathbun. This species occurs at the present day on the shores of Puget Sound and presents the same form of parasitism, being an interesting case of a continuous parasitic condition over thousands of years.

[6] James W. Mavor: On the Occurrence of a Parasite of the Pike in Europe, *Myxidium lieberkühni* Bütschli, in the Pike on the American Continent and its Significance. Biol. Bull., no. 5, 1916, 376.

[7] Vernon L. Kellogg: Mallophaga in Genera Insectorum, 1908, 66me fascicule, p. 3.

[8] Described by Miss Mary J. Rathbun, American Journal of Science, Volume 41, 1916, p. 345.

CHAPTER IX

THE BACTERIOLOGY OF PAST GEOLOGICAL AGES

The oldest bacteria. Bacteria and thread-mould in the Devonian. Bacteria of the coal and other fossil bacteria. Coprolites of the Autun schists. Bacteria of the coprolites. Fossil bacteria analogous to those which produce dental caries. Bacteria in the American Permian. Microscopic observations on coprolites from the American Permian. Descriptions of Figure 26 and Plates LIX–LXV illustrating Chapters VIII and IX. Figure 26 and Plates LIX–LXV.

It will of course be evident, with but little consideration, that our knowledge of bacteria of past ages is exceedingly scanty, and our conclusions insecure. It seems, however, very proper to record in this chapter what little is known of these ancient forms of life and to determine, if possible, their relation to the origin of disease. There are two ways in which we may gain a knowledge of ancient bacteria. 1). By actual observation of the bacilli or cocci, or their spores, in thin sections of rock. 2). By inferring their presence from results which today are due to the action of bacteria.

The determination of the ovoid and rounded bodies in a fossil condition as bacteria, distrusted at first, is coming to be recognized[1] by bacteriologists and pathologists although it must still be constantly borne in mind that mistakes are more likely to occur in this branch of investigation[2] than almost any other phase of paleopathology; a subject entirely beset with difficulties.

It is not my purpose here to comment on the origin[3] and evolution of bacteria but merely to call attention to their possible influence in

[1] J. G. Adami: The Antiquity of the Bacteria in "Medical Contributions to the Study of Evolution," pp. 16–18, N. Y., 1918.

[2] C. E. Bertrand: Figures bacteriformes dues á des causes diverses; épaississements cellulaires, plastides libérées, précipités ferrugineux. Ass. franc. Avanc. Sc. Congr. Lille, pp. 600–606, 1909.

[3] H. F. Osborn: Evolution of Bacteria, in "The Origin and Evolution of Life," pp. 80–90, N. Y., 1917.

R. S. Breed, H. J. Conn and J. C. Baker: Comments on the Evolution and Classification of Bacteria. J. Bacteriol., Balt., iii, no. 5, 445–459.

R. E. Buchanan: Bacterial Phylogeny as indicated by modern Types. Amer. Naturalist, LII, 233–246, 1918.

the origin of zymotic diseases[4] and to show their presence in the world of life at a very early time.

THE OLDEST BACTERIA

Germs are among the oldest inhabitants of the earth. It has even been suggested that while the earth was still in the process of building by the accretion of meteorites bacteria were carried to the earth from distant planets and thus initiated life on earth. However this may be, bacteria have actually been found in the oldest fossil bearing rocks of North America, having been discovered in 1914 by Dr. Charles D. Walcott. These were found in association with algal deposits of the Newland limestone, a formation of the Beltian series of Algonkian (Pre-Cambrian) rocks of central Montana. Walcott had previously suspected the activity of bacteria as an important factor in the deposition of the Algonkian limestones.[5] This curious activity of recent bacteria has been noted by Drew[6] and is an interesting commentary on the persistence of a single type of life with similar activities during the entire period of geological time. Walcott announced his discovery the following year[7] and later discussed the bacteria in their relation to primitive life[8] as revealed by Pre-Cambrian and Cambrian fossils. His results were received with the greatest interest. While not directly related to disease his discovery reveals the presence of a type of life so important to disease, at the very beginning of the geological history of animals.

The form of these most ancient germs is so similar (Plate LX) to that of recent bacteria that they are referred to the *Micrococcus*, a common recent bacterial form. Considerable comment has been aroused as to the possibility of such delicate organisms as bacteria being capable of preservation in a fossilized condition. This is, how-

[4] J. G. Adami: The Antiquity of Zymotic Diseases in "Medical Contributions to the Study of Evolution" pp. 15–16, N. Y., 1918.

The Antiquity of Disease; What the Fossils Reveal to Paleopathologists. Current Comment in J. Am. Med. Assn., Chicago, lxxi, p. 1829, 1918.

[5] C. D. Walcott: Pre-Cambrian Algonkian Algal Flora. Smithson. Misc. Coll., Wash., lxiv, no. 2, no. 2271, pp. 94–95, 1914.

[6] G. Harold Drew: On the Precipitation of Calcium Carbonate in the Sea by Marine Bacteria, and on the Action of Denitrifying Bacteria in Tropical and Temperate Seas.

Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, v, 7–45, 1914.

[7] C. D. Walcott: Discovery of Algonkian Bacteria. Proc. Natl. Acad. Sci., i, 256, figs. 2–3, 1915.

[8] C. D. Walcott: Evidences of Primitive Life. Smithson. Rept. for 1915, 241, pl. 4, 1915.

ver, pretty definitely settled by investigators in other lines who have hown that fossil brains, fossil flowers, fossil blood cells, muscle and :idney structures are known to be so well preserved as to permit an xamination of the minute structure of the tissues. Renault and Van Tieghem, too, have shown that bacteria in later geological ages are apable of perfect preservation.

Disease, however, did not exist with the most ancient bacteria. They were harmless, as are most of the present-day bacteria. Whether bacterial organisms were instrumental in effecting the origin of disease we do not know. This is a wide field of study which has not yet been explored. In a later geological period bacteria have been found n partially decayed bone, together with thread mould and other types of fungi. This condition, however, cannot be regarded as disease but as decay in dead material. The earliest animals were apparently free from disease, although they were subject to injuries incident to the life of any creature.

The bacteria discovered by Walcott (Plate LX) consisted of individual cells and apparent chains of cells which correspond in their physical appearance with the cells of *Micrococcus*. Analogous forms of bacteria are commonly seen in many recent diseases.

This was not the earliest discovery of bacteria in a fossil state, however, since Van Tieghem[9] had described Paleozoic bacteria in 1879. These were found in silicified vegetable remains from the Coal Measures of St. Étienne, France, where the cellulose membranes showed traces of fermentation such as is produced by bacilli at the present day. Since that time a number of interesting papers have appeared from the pens of Van Tieghem and Renault[10] who found bacteria in all kinds of vegetable and animal débris. Renault has incorporated his results in a volume which is referred to more extensively in a succeeding section of this chapter.

BACTERIA AND THREAD-MOULD IN THE DEVONIAN

The presence of bacteria in the middle Paleozoic was announced by Renault (1896.2) based on the study of plant and animal material from the Devonian schists of Staasfeld. Bacteria are thus not confined to the Carboniferous since they have been described from organic remains in the upper Devonian and are known as *Micrococcus devoni-*

[9] Clement Reid: Art. Paleobotany in "Ency. Britan.," 11th ed., 1911, p. 525.

[10] These papers are listed by Erwin F. Smith: Bacteria in Relation to Plant Diseases. Carnegie Inst. Wash., Publ. 27, Vol. 1, 1905.

cus,[11] in two varieties. These microorganisms were found in portions of the plant *Cordaixylon*. In a transverse section of the wood certain vascular spaces are occupied by spherical bodies, slightly reddish in color, measuring when not deformed from 2.2 to 3 microns in diameter. Occasionally they present the appearance of Diplococci, being often found aggregated in masses of irregular shape resulting from their disintegration. These bacteria of Devonian age (Plate LXIV) are thus seen to be microorganisms of disintegration of dead tissue and are not known to be related to disease.

Similar observations have been recorded by the author[12] when he noted the presence of mould and bacteria in the almost disrupted lacunar spaces of the ancient vertebrates, *Bothriolepis* and *Coccosteus*, from the Devonian of Canada and Scotland.

The occurrence of thread moulds (*Mycelites ossifragus*) in the hard parts of invertebrates and vertebrates,[13] from molluscs to man, has been noted for more than eighty years and the literature is very extensive. The canals made by the penetrating moulds, known as the *canals of Roux or Wedl*, have been noted by Kölliker in the hard parts of invertebrates, fossil and recent; by Triepel in recent human bones; by Schaffer in ancient human teeth; by Sonders in a Neolithic skull; and by Roux in the skeletal parts of vertebrates, Carboniferous to recent. Since they occur likewise in the hard parts of Devonian vertebrates they doubtless have a very wide distribution and may be regarded as one of the most ancient types of organisms in existence.

There is nothing peculiar in their existence in the ancient vertebrates except that their course of growth is modified by the histology of the ancient bone. In the absence of definite lamellae the mycelia often seek out a lacuna, enter it and growing out in the direction of the brief canaliculi expand both the lacuna and canaliculi until the entire structure is disrupted and the canals meet other canals growing out from adjoining lacunae. In modern human bone the mycelia very often follow the interlamellar spaces, but ancient bone seldom has any definite spaces of this kind, and more often fossil bone tissue is to be

[11] B. Renault: Sur quelques Microorganismes des combustibles fossiles, Bull. de la Soc. de l'Industrie Minérale xiv. pp. 351–353, pl. xxv, figs. 11–14.

[12] Roy L. Moodie: Thread Moulds and Bacteria in the Devonian. Science, N. S., LI, no. 1305, 14–15, January 2nd, 1920.

[13] References to the literature and a more complete account of these moulds is given by the author in his paper: "The Elements of the Haversian System in normal and pathological Structures among fossil Vertebrates." Williston Memorial Volume. Since their relation to disease is very uncertain further discussion of them will not be given here.

garded as an osteoid substance without any lamellae and with only cattered lacunae. That the appearance of the described lacunae is ot normal is easily checked by a study of normal lacunae in the adacent material. A single microscopic field (Plate LXIV) will show oth normal and invaded lacunae. The canals, from 2-4 microns in iameter, have an undulating course and offer easy channels of entrance o invading bacteria.

The presence of these thread moulds would seem to indicate that he piece of bone showing them was preserved in a moist, sandy or nuddy place close to the shore, thus agreeing with our previous onceptions of the preservation of fossil material. It is difficult to see ow the moulds would find entrance if the material were embedded nder sand or silt in deep water. The ancient Egyptian mummies, uried for thousands of years in the dry, hot sands of the Nubian desrts do not show such canals, nor do the Cretaceous vertebrates from Kansas show them. Seitz [14] has figured them, though he apparently did ot recognize their nature, in the bones of labyrinthodonts and dinoaurs. They have also been seen in sections of the vertebra of an American sauropod dinosaur.

The bacteria (Plate LXIV) doubtless have entered the bone along he course of the *Canals of Roux* and may readily be detected by the eady, nodular appearance of the canal.[15] Often the bacteria, in *Bothriolepis* for instance, have invaded a canaliculus which the *Mycelites* lid not find. The small clumps, or nodes, may clearly be regarded as colonies of bacteria and doubtless a form of *Micrococcus*, and related to hose described by Renault in the dentinal tubules of Permian fishes. The beady appearance of an invaded *canal of Roux* or canaliculus recalls exactly the picture of the invaded dentinal tubules in cases of human dental caries.[16]

While these conditions are not to be regarded as disease but rather as the agents of decay yet they so closely resemble conditions of disease and they are so ancient it is thought worth while to incorporate them.

[14] Adolf Leo Ludwig Seitz: Vergleichende Studien über den mikroskopischen Knochenbau fossiler und rezenter Reptilien und dessen Bedeutung für das Wachstum und Umbildung des Knochengewebes im allgemeinen. Nova Acta. Abh. d. Kaiserl. Leop.-Carol. Deutschen Akad. d. Naturforscher. Halle. lxxxvii, no. 2, pl. xi, fig. 6, 1907.

[15] The condition in these ancient carapaces is identical with the occurrence of bacteria in the scales and teeth of Permian fishes described by Renault: Sur quelques Microorganismes etc., p. 213, fig. 37.

[16] F. B. Noyes: Dental Histology, fig. 19.

BACTERIA OF THE COAL AND OTHER FOSSIL BACTERIA

Our knowledge of the bacteriology of the geological ages succeeding the Devonian is due largely to the work of Bernard Renault,[17] who summarized his researches and those of his associates in France in a magnificent work, on the microorganisms (Plate LXII) of the coal. This work gives the results of 24 years of activity and will serve for all time as a monument to its author. He defines *Microorganisms* as the microscopic remains of plants and animals which have been determined in the fossil fuel.

Renault has divided his study into nine sections:

1). Study of the Microorganisms of some peats.
2). Study of the Microorganisms of some lignites.
3). Study of the Microorganisms of some recent bituminous schists.
4). Study of the Microorganisms of some Bogheads. (Coal).
5). Study of the Microorganisms of some Cannels.
6). Study of the Microorganisms of some coals.
7). Study of the Microorganisms of some ancient bituminous schists.
8). Study of the Microorganisms preserved by silicification.
9). Conclusions.

Since in these discussions he has defined the bacteria found in coprolites, or petrified feces (Plate LXI) of fishes and reptiles, as well as in ancient ichthyodorulites, or fragments of bone isolated in the rock, Renault's work is of fundamental importance to a study of Paleopathology. In stomach contents and in the teeth and jaws of fossil vertebrates Renault found evidence of bacteria. Especially important is his discussion of the early occurrence of *caries* due, as he thought, to five types of bacteria. This interpretation was based on the study of decayed spots within the substance of bones and teeth of fossil fishes. He named the bacillus which seemed most active in this disease *Bacillus lepidophagus arcuatus*.

That the reader may have at his command the results of Renault I am devoting the following pages to a free translation of his work regarding the bacteria and fungi (Plate LXII) of the ancient bituminous schists of the Permian of Autun, France, beginning with his discussion of the:

[17] B. Renault: Sur quelques Microorganismes des Combustibles fossiles. Bull. Soc. de l'Industrie Minérale Saint Étienne. Tome xiii, 1899; Tome xiv, 1900. With a folio volume of 21 plates containing nearly 300 microphotographs of the minute plant and animal forms, chiefly bacteria and fungi.

COPROLITES OF THE AUTUN SCHISTS

Fishes, reptiles and amphibians inhabited the Autun lake during the entire time of its silting up, as is abundantly proven by the great numbers of scales, fins, and bones which are found at all levels.

The researches of Gaudry[18] have rendered classic the discoveries which that noted scholar made among the fossil reptiles of Igornay, Margenne, and Thélots. He also called our attention to the considerable quantity of organic matter, fats, oils, nitrogenous and cartilaginous substances, which had resulted from the creatures enclosed within the schists. The majority of these substances had disappeared, but the resistance of fatty substances to decomposition, especially when deprived of air, is well known. It is therefore not impossible that although more or less modified they contributed to the formation of the products produced by distillation.

It has already been remarked that the microscope fails to show bacteria in the mineral portion of the schists, but these schists likewise contain a number of coprolites of fishes and reptiles which serve as very favorable media for the multiplication of these minute organisms. A number of these are figured, showing the distribution of microorganisms within these fecal remains (Plate LXI).

BACTERIA OF THE COPROLITES

It is well known that certain fishes have in their rectum a spiral valve which gives to the extruded feces (Plate LXI) an irregular ellipsoidal form, with characteristic markings.

Rarely coprolites are found isolated in the schists, the greater number being assembled in certain areas, as if the fishes had lived in swarms in the old Permian lake. Frequently, on sectioning (Plate LXIII) a coprolite, one finds remains of bone and scales of variable size, of small teeth, morsels of food; the residue of the process of digestion. The presence of all these solid parts has contributed to the preservation of the coprolite and in them are found various types of bacteria.

[18] ALBERT GAUDRY—a noted French vertebrate paleontologist, 1827–1908. His interests were largely philosophic and his investigations resulted in the publication of two important evolutionary works: *Enchaînement du Monde animal dans les temps géologiques*, and *Essai de Paléontologie philosophique*. These are most useful presentations of paleontological facts of evolutionary significance. Gaudry was an earnest worker and produced some 218 contributions to paleontological and geological literature. In 1872 Gaudry became professor in the Museum of Natural History in Paris, was a member of the Geological society of France and a member of the Institute.

The state of alteration of the bones within the coprolites is extremely variable. Often the osseous lacunae are preserved entire, again they are unrecognizable and appear as a homogeneous mass.

A preparation of fossil bone (Plate LXIII and LXV) serves to show the excellent preservation in which one finds the fragments of fossil tissue. For anatomical purposes one is compelled to inject coloring materials in order to show in recent bone the canaliculi of the lacunae. In the fossil the injection has been made by the blood of the organism, which on fossilization becomes black and opaque. The lacunae are polyhedral, longer in one direction; some of them attaining a maximum length of 13 microns, the shortest 4 microns. The canaliculi have a diameter of 9 microns at the point of origin, but after two or three divisions the diameter is reduced to 2 microns. Renault searched in vain for blood corpuscles[19] in the great vessels, but the coagulated mass is entirely opaque.

The diameter of the canaliculi, radiating out from the lacunae, is too narrow to allow the passage of blood corpuscles, but sufficiently large, near the cavity of the lacuna, to permit the entrance of micrococcids (Plate LIII). By referring to figure b, plate LXIII one sees the methods of formation of the first and second types of anastomoses of the canaliculi. Where the cell is best in focus the canaliculi measure 1 micron. At this point they are filled with Micrococci of which some measure 0.8 and others 0.5 microns. Often they are so close together as to touch and form a continuous line. It seems that the *Cocci* of small size began to augment the diameter of the canaliculi, which were thus enabled to receive those of larger size. In plate LXIII, fig. b, the canaliculi are shown notably enlarged and filled with Micrococci. But in many of the canaliculi, together with the Cocci there are numerous droplets of solidified substance which one may easily confuse with the bacteria. These droplets often take an elongate form, exhibiting very unequal dimensions, often closely comparable to those of the Micrococci. Their primitive fluid state has permitted them to unite and often to completely fill some of the canaliculi.

Other examples of a similar vascular network, which are very well preserved, though not often found in coprolites, but which accompany them in the schists, are in the *Ichthyodorulithes*, or isolated fragments of fossil fish bone. These objects often represent portions of fins or fin rays such as those which support the dorsal fins and have acquired a

[19] The possibilities of the structures being fossilized is discussed by the author: Concerning the Fossilization of Blood Corpuscles. Amer. Naturalist, LIV, 460–464, 1 fig. 1920.

notable development in placoid fishes of the elasmobranch group, such as the genera: *Onchus*, *Ctenodus*, *Byssacanthus*, *Pleuracanthus*, etc. The ichthyodorulite which we shall describe belongs to the genus *Pleuracanthus*, and was discovered in the same beds by Roche, as were the coprolites of Igornay, at a depth of 150 feet.

Renault calls attention to a section (Plate XXVII, fig. 8 of his monograph) which is shown at an enlargement of 200 diameters. It is a tangential section through the cortical region of an Ichthyodorulite and is extremely rich in vascular networks, which, as seen in the photomicrograph, are already distorted by bacteria; shown in detail at a higher magnification in his Figure 9. One may thus distinguish in an examination of this material many rami with smaller branches which apparently retain the same diameter throughout. The smaller branches either anastomose to form a closed network or at other times end abruptly. The portion of network figured by Renault shows near the center a union of numerous inferior and superior branches; not clearly shown in the photograph because of the depth of focus required to show the union. At other points these rami are in communication with the canaliculi, apparently analogous with those which unite the lacunae with each other. The rami of the principal plexus, of which only a part is figured, measure 6-7 microns in diameter. They are filled with a brownish substance, in the midst of which are found clear, colorless, spherical, ovoid or slightly cylindrical bodies, the diameters of which vary from 1.6-6 microns. These globules recall those which had already been described by Renault as derived from the blood, but their contours are better defined. There are to be seen in the midst of these globules coccoid forms which Renault is inclined to regard as *Micrococcus*. It is apparent that the globules are not the result of disorganization of the adjacent osseous material, but that they were contained in the substance, black when petrified, which had filled the plexus during life. This was possibly blood or a fluid derived from the blood.

Renault then shows (Renault's Figures 5 and 7, plate xxvi) the cavities of the lacunae enlarged and distorted, quite the same as in the bone fragments preserved in coprolites. The disturbing agent was the bacteria. In the interior of the lacunae there is a yellowish material, a little darker than the periphery. This is continued, without interruption, into the canaliculi. No micrococci can be detected in this material. When they do contain some such figures they are of an ovoid or irregular form, a little larger than the size of the Cocci, and doubtfully related to them.

The concentric osseous lamellae, which occur around the lacunae, are not distinct. It is clear that Cocci are more abundant in the regions of the canaliculi near the lacunae. They are also found at points where the diameter of the canaliculi are slightly enlarged.

Certain sections (Renault's Figures 6 & 8, Plate xxvi) show the complete disorganization of the lacunae and their canaliculi have disappeared. In the resulting amorphous material the spherical bodies are seen, unequal in size, arranged in lines, scattered; the small yellow masses irregular. It is difficult to decide on the nature of the spherical bodies as well as the irregular ones. Perhaps they are the result of bacterial activity on the softer material which, in life, was contained within the lacunae. There are numerous spherical masses, similar to Micrococci, which may be distinguished from the true Cocci by their size of 4 microns, as well as by their reddish-brown tinge which is darker than that of the Cocci.

Thus it is clear that the lacunae of scales and bone are invaded by bacteria, one after another, by means of the canaliculi; ending in the complete disorganization of the osseous material, and taking on the form of an amorphous mass, holding the bacteria in suspension, as well as the spherical and irregular masses. Often this invaded osseous material was accompanied in certain structures, such as scales, teeth, Ichthyodorulites, etc., by layers of dentine or enamel. The lacunae of dentine have a different form from those of the osseous lacunae. They are prismatic, and each one is traversed axially by an extremely minute canaliculus.

There are found in such substances (Plate LXV) in the lacunae, when cut parallel, an invasion of Micrococci which have entered a canaliculus of which the diameter is 0.8 microns. The cavity of the prismatic lacunae is occupied by a *Micrococcus* of different size, representing a distinct variety. Similar instances of the occurrence of Micrococci have been seen in the dermal shields of certain fish-like vertebrates from the Devonian of America.

Bacilli seem to be more abundant in fragments of scales than the Micrococci. Renault has distinguished the following varieties of *Micrococcus*, which he has grouped under the name *Micrococcus lepidophagus*.

Micrococcus lepidophagus, Var. *a*.—Spherical cells with clear contours, often presenting themselves under the aspect of a cloudy mass composed of small black dots which measure from 0. 4 to 0.5

microns in diameter. They are often disposed in linear chains of from 2 to 4 individuals.

Micrococcus lepidophagus, var. *g*.—Spherical cells with contours clear and colored; the interior sometimes deeper in color. They measure 0.8 microns. They are found distributed in groups of two and four.

Micrococcus lepidophagus, var. *b*.—Spherical cells with contours clear and colored, measuring 1.2 microns. This variety may easily be confused with the preceding and they are often found together.

Micrococcus lepidophagus, var. *c*.—Spherical cells with very clear contours. The envelope is colored a clear brown; the contents clear without granulations; the diameter attaining 3.2 microns. It is not rare to find these spherical cells divided by a partition or again, united in pairs. This variety does not have the tendency to form in groups or chains, although often the globules are very close to each other and are even aligned in the canaliculi of the lacunae in the dentine.

These varieties are found, often isolated, in distinct lacunae of the dentine; their action on the lacunae being independent and starting at different times.

A certain number of the canaliculi are empty; others occupied by the very small Micrococci, var. *a;* others filled by a mixture of many species. Propagation of bacteria in the dentine or enamel portion of scales is made possible by the small canals connecting the vascular channels, or by the canaliculi of the lacunae in the ivory. In this latter case, the variety *a*, alone, is able to enter readily. One often sees in the interior of many lacunae unique linear strings of bacteria, formed of this variety. When the work of destruction has been sufficiently advanced, other bacteria of a larger diameter are enabled to enter; this is especially true of those regions which are greatly altered, where it is possible to identify the four varieties indicated above.

As for lacunae of true bone, the dentinal lacunae appear to have suffered a complete alteration and the canaliculi have completely disappeared and the boundaries of the lacunae obliterated.

It is impossible to identify fossil bacteria with the different living species, since in identifying these one must know not only their external form but their cultural characteristics. We do not possess other terms of comparison between living and fossil bacteria than those of form and the resemblance in the similarity of products of destruction.

The relations of these bacteria and their results of disintegration of dentine point an analogy to dental caries and Renault devotes a section, which we shall freely translate, to:

FOSSIL BACTERIA ANALOGOUS TO THOSE WHICH PRODUCE DENTAL CARIES

Here we meet for the first time in geological history with bacteria which appear to be definitely related to disease. In the Permian coprolites from Igornay, Renault found in the fragments of scales four types of Micrococci. Other coprolites from the same locality, however, contain bacteria having a shape and form similar to those producing dental caries, as recognized by several scholars.

The phosphate of lime, softened by the bacterial activity, has become sufficiently plastic so that the external outline of the lacunae has disappeared, allowing a mingling of the contents of adjacent lacunae.

A section, cutting a number of scale fragments in a coprolite, shows the cellular space filled with numerous bacteria.

In certain places in the section the periphery of a number of scales is cut and one may distinguish a number of grooves, clearer than the interior of the scale, which follow more or less faithfully the contour of the scale. These grooves are occupied by a great number of bacteria in which the Micrococci are represented by individuals of various forms; some look like spherical globules with clearly limited contours, measuring 3.2 microns, not to be distinguished from *M. lepiodphagus* var. *c.;* others having an average measurement of 1.5 approach in resemblance the *M. lepidophagus* var. *b.* There are also evident, though less numerous, very small Micrococci which are clearly related to *M. lepidophagus* var. *a.*

There are to be observed scattered among these different species of Micrococci a large number of Bacilli, which are evident in the form of black colored objects, isolated, rarely double, and without definite orientation.

These Bacilli, which Renault designates under the name of *Bacillus lepidophagus*, are rectangular cylindrical bodies, having a length of 4.2 to 5.2 microns; their diameter varying from 0.7 to 1 micron.

There are also evident long bacteria, about 4 microns in length, having a diameter of 3 microns which appear to be a form of *Bacterium,* but they may be forms of *Micrococcus* in division.

The alteration of the osseous fragments is extremely variable, even in the same coprolite; often one can distinguish the lacunae; often all structure has disappeared. The more or less homogeneous mass which results shows along the edges various cavities (Plate LXIII) and canals derived from the vascular network, and which are filled with a brown

material. In this part are found the greatest number of bacteria, chief among which is the following form:

Bacillus lepidophagus arcuatus.—This bacillus measures about 4 microns between the two extremities; the shaft attaining a least diameter of 1.4 microns. Occasionally these Bacilli are curved, measuring about 2 microns across the arc, and often two of them joined together end to end, resemble the letter S, recalling a *Spirillus* in form.

Renault shows a section (his Plate xxvi, figs. 13, 14, 15) of some of the fragments which are without structure but which exhibit a considerable number of bacteria. Some of them are bacilli of small form, 2 to 2.5 microns in length, and 0.6 microns in diameter, which are cylindrical with rounded extremities, black in color and are easily distinguished in the midst of the osseous pulp which is of a lighter color. The Micrococci are less numerous. They are perfectly spherical, either black or transparent, with clear contours; with a diameter of 1.3 they form a part of the group designated *Micrococcus lepidophagus* var. *b*.

The mass includes also a great number of irregularly spherical bodies of which the size varies from 2.6 to 4μ. They are black in color and are analogous to those which Renault supposed to be oily droplets, having been carbonized from a fluid state. This hypothesis is justified in part at least by the inclusion of bacilli more or less within the interior of the globules, recalling phagocytes of a very ancient epoch. In fact this may be the only known example of phagocytosis.

The different bacteria which have been mentioned are represented by a number of individuals which are greatly increased in that region where the bone is not yet destroyed. On the edges of the fragments traces of vascular channels are seen, large enough to permit the entrance of bacteria. No Bacilli have been seen in the dentinal tubules of the eburnated portion of the scales, the bacteria present being only the Micrococci. One may suppose that the bacilli were derived from the undigested substance on the edges of the coprolite. The species which are abundant are different from those seen in the interior of the scales and resemble those seen in dentinal tubules and in the osseous part of teeth.

Miller has described five different types of recent bacteria as causing dental caries, which may be designated by the letters *a*, *b*, *c*, *d*, *e*. The bacteria *a* and *b* are Cocci or Diplococci, isolated or in chain formation. The bacteria *b* resembles in its structure a *Bacteridium*. The bacteria are composed of very small cocci, rarely associated in chains. The

Cocci of the bacteria *d* are larger than those of group *c*. Finally the bacteria of group *e* represent the small comma bacteria. When two of these forms are adjacent they form the letter *S*, and when a great number are joined together they resemble the *Spirillus*.

On placing the above described bacteria on uninfected teeth Miller has obtained artificial caries identical with spontaneous caries. One may see in his preparations, as well as in the fossil sections described by Renault, the canaliculi filled with bacteria.

Galippe and Vignal have seen in caries of the teeth: 1) a short bacillus; 2) a bacillus twice as long and twice the diameter, attaining a length of 3 microns, somewhat constricted in the middle; 3) a bacillus resembling the preceding but without the constriction; 4) a very short, very thin bacillus, almost as wide as long; 5) a bacillus with rounded extremities, with a length of 4.5 microns; 6) numerous Micrococci attaining a length of 5 microns.

According to the description Renault gives, and which is discussed above, of the varieties of *Micrococcus lepidophagus*, found in osseous eburnated plates, as well as the bacilli either evident or inferred which accompany them, one may conclude that the destruction of bone, or eburnated plates and teeth, in ancient times, was performed by the work of Micrococci and Bacilli, the form and proportions of which approach in a remarkable manner those of bacteria which, at the present day, are the cause of *caries* of bone and teeth.

Renault did not attempt to identify the fossil species which he described with those discussed by Miller, Galippe and Vignal, since such a determination could be controlled only by means of cultures. There remains consequently a doubt, which is impossible to settle, as to whether the means of destruction in fossil and recent bones and teeth is due to the same types of bacteria. His observations are extremely important, however, in pointing out an analogous situation in paleopathology in this particular case of caries; a form of pathology easily susceptible of fossilization. It is, of course, impossible at the present time to say whether the decayed spots seen by Renault on the edges of bone, scales and teeth are the result of caries while the animal was alive, or whether it is merely a state in the disintegration of dead material.

It is interesting to note the abundance of bacteria, Micrococci and Bacilli being equally abundant, within the undigested substance around the coprolites, indicating very clearly that the bacteria had developed within this food substance during the progress of digestion, and were preserved on account of their being enclosed by the spiral folding of

he undigested portions. They are found irregularly scattered throughut all of the covering of the coprolite. The bacilli are regarded by enault as belonging to several species which he has designated: *acillus permiensis*, *B. granosus*, *B. lallyensis* and *B. flaccidus*. Since he nature of these bacteria is doubtful and their relation to disease unertain it will suffice to mention their occurrence.

BACTERIA IN THE AMERICAN PERMIAN

The presence of bacteria in the closing period of the American aleozoic is suggested by the condition of the fractured and infected pine (Plate XV, a), resembling an osteomyelitis (Plate XXI). Study f microscopic sections of this spine, described in Chapter VII, based on our transverse sections at different levels show in detail the nature of he enclosed sinuses which produced the apparent tumefaction. Careul search through the sections has failed to reveal any sequestrum, such s is commonly found in modern examples of chronic osteomyelitis, or were bacteria found in the margins of the calcite-filled sinuses. The resence of pathogenic bacteria in such a situation would be rather are in a fossil state, since the nature of the fossilization processes would sually destroy them. It is doubtful too whether we could prove the athogenicity of such bacteria save by their location.

Bacteria of the *Micrococcus* type, so common in the fossil verterate material studied by Renault from the Autun of France, are howver abundantly preserved in the distorted osseous lacunae (Plate XV). They are similar in all respects to those (Plate LXIV) occurring n the fossil bone of fishes previously described in this chapter under the eading "Bacteria and Thread Mould from the Devonian." The acteria, in the osseous lacunae of the Permian spine, often seen isolated n the terminal bulb of the canaliculus-like burrows, which radiate out rom the body of the lacunae, are no doubt those of decay, and had othing to do with the infection producing the osteomyelitis. There eems little doubt that bacteria of the present type may be found in ny fossil vertebrate material of the type which has been embedded in noist ground long enough to undergo a slight amount of decay, prior to ossilization.

The bodies which have been interpreted as bacteria, when seen solated at a magnification of 1240 diameters, measuring from 1 to .5 microns, appear as semicrystalline, rounded, brownish bodies reembling minute specks of amber. The question as to whether they are eally bacteria has been satisfactorily discussed by the researches of

Renault and others, who have placed the subject of the bacteriology of fossil vertebrate remains on a safe footing. Those seen in the present sections often group themselves in pairs recalling the modern Diplococci. I have never seen chains of these forms in vertebrate material. Photomicrographs of these sections were not made since the bacteria have all the appearances seen in the photomicrographs of a spicule of bone embedded in a coprolite shown in Plate LXV, d.

MICROSCOPIC OBSERVATIONS ON COPROLITES FROM THE AMERICAN PERMIAN

The nature of the form and construction of coprolites, fossil feces, is shown in Plate LXI. They have been abundantly described and figured by Renault, Neumayer,[20] Leydig, Duvernoy, Bertrand, Agassiz, Gaudry and von Ammon. While most of these remains are regarded, on account of the spiral form, as excreta of fishes of the *Ceratodus* type, there seems to be some ground for regarding a few of them as derived from Stegocephalia and reptiles. Some writers have even postulated a spiral valve in the rectum of the Permian reptiles on the basis of the form of the coprolites preserved in the beds with the reptilian skeletons.

The coprolite shown in the photomicrographs (Plate LXV) I should regard as being derived from a fish on account of the arrangement of the material in folds around the spirals of the rectal valve and the rugae which are particularly well shown in Figure a of Plate LXV. The dark spots represent carbonized partially digested food material and some of the white bars represent spicules and flakes of bone, scales and teeth. Often from the shape of an undigested fragment of bone one is enabled to diagnose the nature of the animal devoured. There are two complete layers and portions of two others shown in this photomicrograph (Plate LXV, a). The next figure "b" illustrates the nature of the fecal material, at a magnification of 200 diameters. The broad band at the top is a flake of bone surrounded by fossilized excrement. The succeeding photomicrographs show the nature of a slender spicule of bone and the bacteria found in the enlarged canaliculi. The lacunae shown in "d" are greatly distorted as may be observed on comparison with normal bone from the same beds. The distortion is interpreted as being due to the entrance of putrifying bacteria during the passage of the bolus of food through the alimentary tract. A careful examination of the course of

[20] L. Neumayer.: Die Koprolithen des Perms von Texas. Paleontographica, LI, 121-127, 1 pl.

he canaliculi will reveal here and there places which have a beaded ppearance which have been interpreted as being due to the presence of small colonies of bacteria, which may be found isolated in the terminal portions of the canaliculi but are difficult to represent in a photomicrograph on account of the refraction of light by the walls of the canaliculi.

DESCRIPTIONS OF FIGURE 26 AND PLATES LIX–LXV ILLUSTRATING CHAPTERS VIII AND IX

FIGURE 26

1-b. Two crinoids, *Barycrinus hoveyi*, with the starfish, *Onychaster flexibilis* intertwined within the arms, doubtless fossilized in the act of feeding on the crinoid's waste. Specimens from the Mississippian of Crawfordsville, Indiana. (After Clarke.)

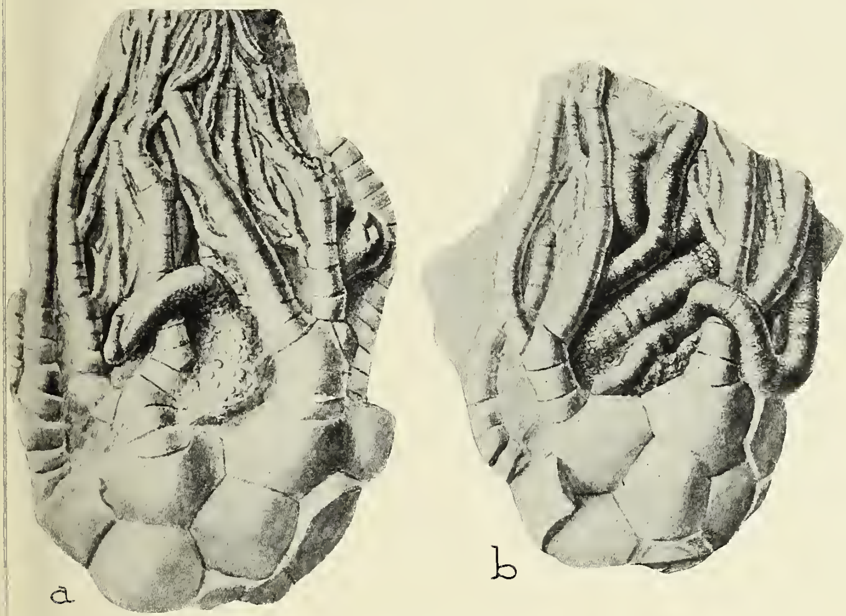


FIGURE 26

PLATE LIX

PLATE LIX

PALEOZOIC PARASITISM

a. A part of the tegmen of a fossil crinoid *Strotocrinus regalis* Hall, showing the successive growth marks made by an attached snail, *Platyceras*, (See Plate XI) which always kept its anterior extremity over the anal aperture (indicated at "A") of the crinoid. From the Mississippian of Crawfordsville, Indiana. (After Clarke.)

b. A mineralized geode formed in the stem of a crinoid which has nothing whatever to do with disease. These geodes in their early stages of growth often look like swollen crinoid stems due to disease, as shown in "f." The geodes occur abundantly in the Keokuk limestone.

c. A crinoid "gall" in the arm of a recent crinoid. The swelling is due to the presence of a myzostomid acting as a parasite. This is for comparison with the fossil "gall" shown in "f." (After Graff.)

d. Section through a fossil coral, *Pleurodictyum problematicum*, from the Lower Devonian of Eifel, showing a worm tube near the center. An example of ancient commensalism. (After Stromer von Reichenbach.)

e. Portion of a parasitized crinoid stem from the Carboniferous of Germany showing carbonized remains of a myzostomid which was the parasite producing the lesion. (After Graff.)

f. Parasitized crinoid stem, a crinoid "gall," from the Carboniferous of Germany, showing the tumor-like lesion produced by the action of the myzostomid (After Graff.)

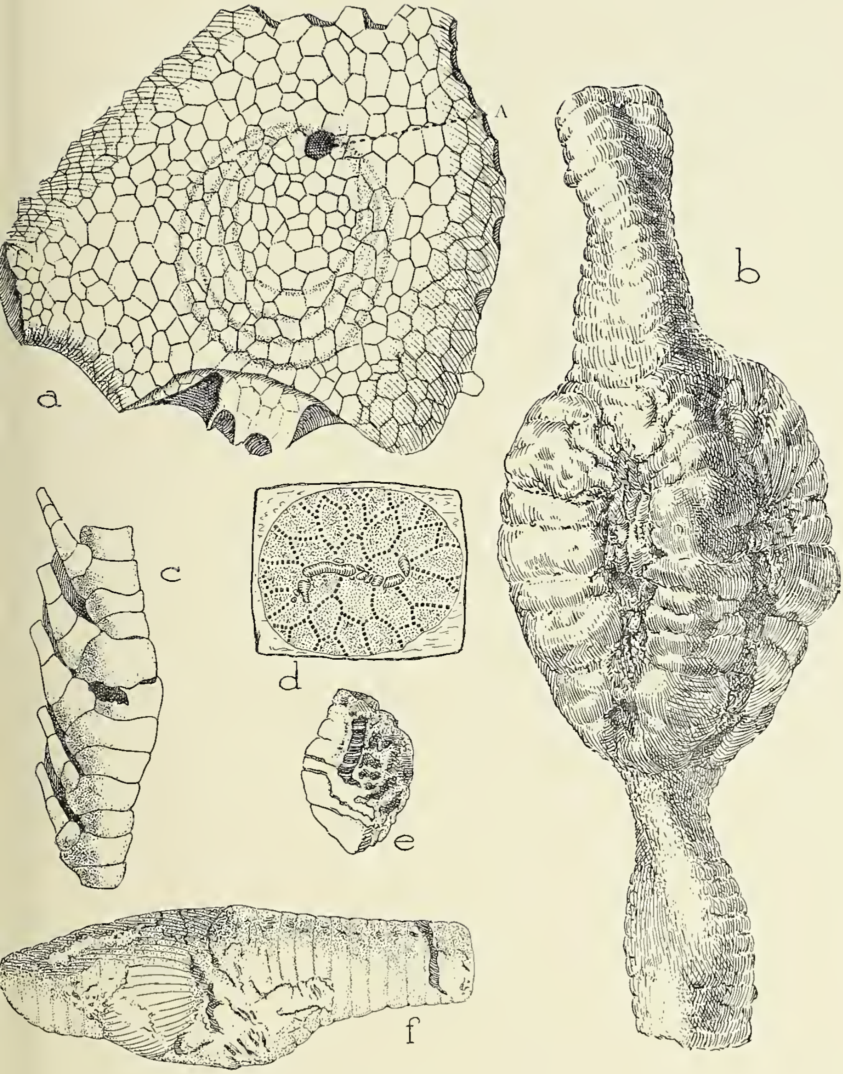


Plate LIX

PLATE LX

PLATE LX

THE OLDEST KNOWN BACTERIA

a and b. Micrococcus sp. undt. (X about 1100 diameters), average size of Micrococci 0.95 to 1.3 micra in diameter. Algonkian; Gallatin Formation, Montana. (After Walcott.)

c. Staphylococcus (?) isolated from Pemphigus neonatorum. Gram stain. X 1200. Kindness of Dr. F. H. Falls.

d. Characteristic groups of *Microccocus vaccinae* (After Cohn.) Very highly magnified.

The oldest known bacteria had no relation to disease. The chains figured here were discovered by Dr. Charles D. Walcott of the Smithsonian Institution, in association with the earliest plants and animals, in the very early stages of the earth's history. It has been suggested that these bacteria were of the type which cause the deposition of calcium from sea water. They are associated with algae which may be seen in the broad stripes running diagonally across the field.

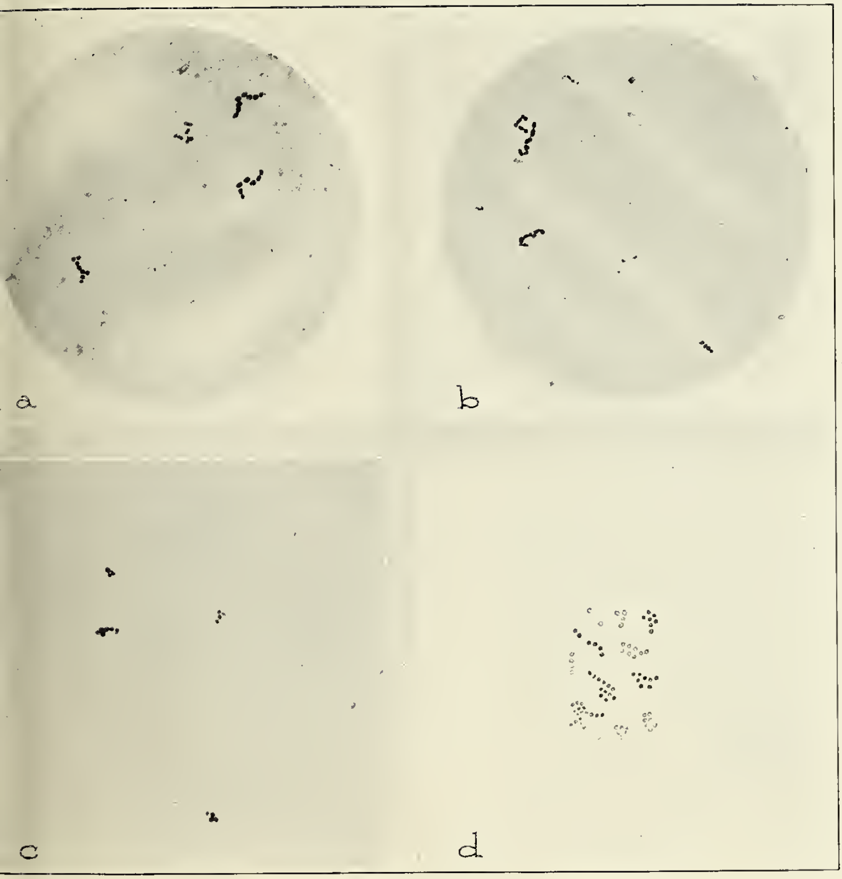


PLATE LX

PLATE LXI

PLATE LXI

FOSSIL FECES

a. An American Paleozoic coprolite, showing in the banded arrangement of materials the effect of the rectal spiral valve.

b. A coprolite of Igornay, France, shown natural size. At the anterior end are clearly seen the bands of material which are laid one on another and thus form the mass of the coprolite. It seems probable that the excrement was deposited on the sandy bottom, or buried immediately in the silt, for if they had been exposed for some time to the action of the water, their external contours would have been less clear, and their form partially destroyed. (After Renault.)

c. Photograph, slightly enlarged, of a transverse section of a Permian coprolite from Texas. A drawing of this coprolite is shown in Plate LXVI, c.

d. A transverse section shows clearly the spiral turns of fecal matter, which had been arranged by the spiral valve. The outer layer is composed of the schist in which the coprolite was embedded. (After Renault.)

e. Transverse section of a fish coprolite from the Permian of Texas. (After Neumayer.)

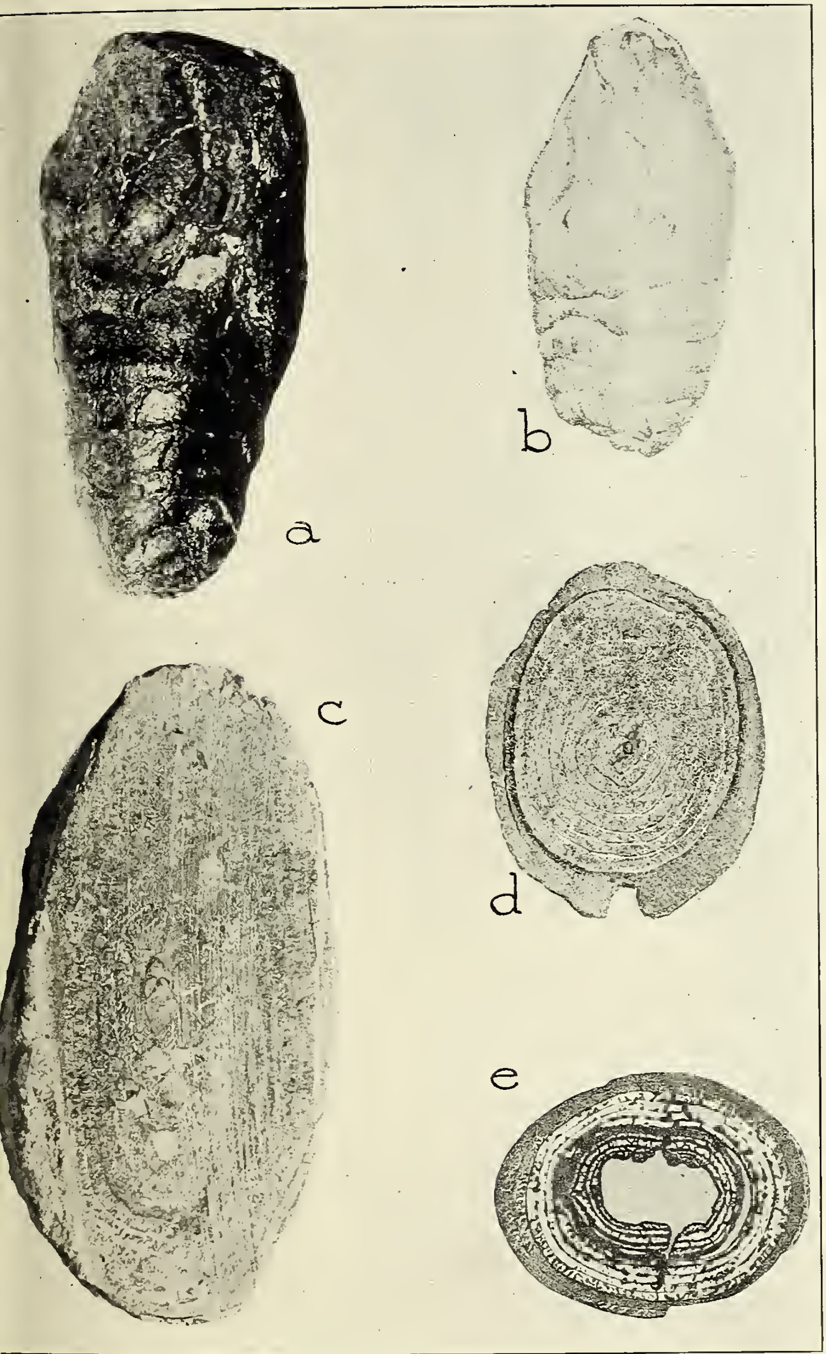


Plate LXI

PLATE LXII

PLATE LXII

ANCIENT BACTERIA AND FUNGI

a. Colonies or "cultures" of bacteria are often fossilized. They have been found abundantly by Bernard Renault in his extensive studies of the minute organisms of the coal. The culture shown is preserved in silicon and had no relation to disease so far as known. Although bacteria existed at the time when disease begins to be apparent among the relics of animal and plant life they were not the immediate cause of disease.

b. Mycelia and sporangia of fossil fungi as seen under high magnification in a thin section of fossil wood, favorite places for growths of ancient bacteria and fungi.

c. Scattered bacteria in plant cells. One of the bacilli shows a mucoid capsule.

d. Other fossil plant cells, at a lower magnification, showing scattered bacteria.

All figures taken from Renault's "Microorganismes des combustibles fossiles."

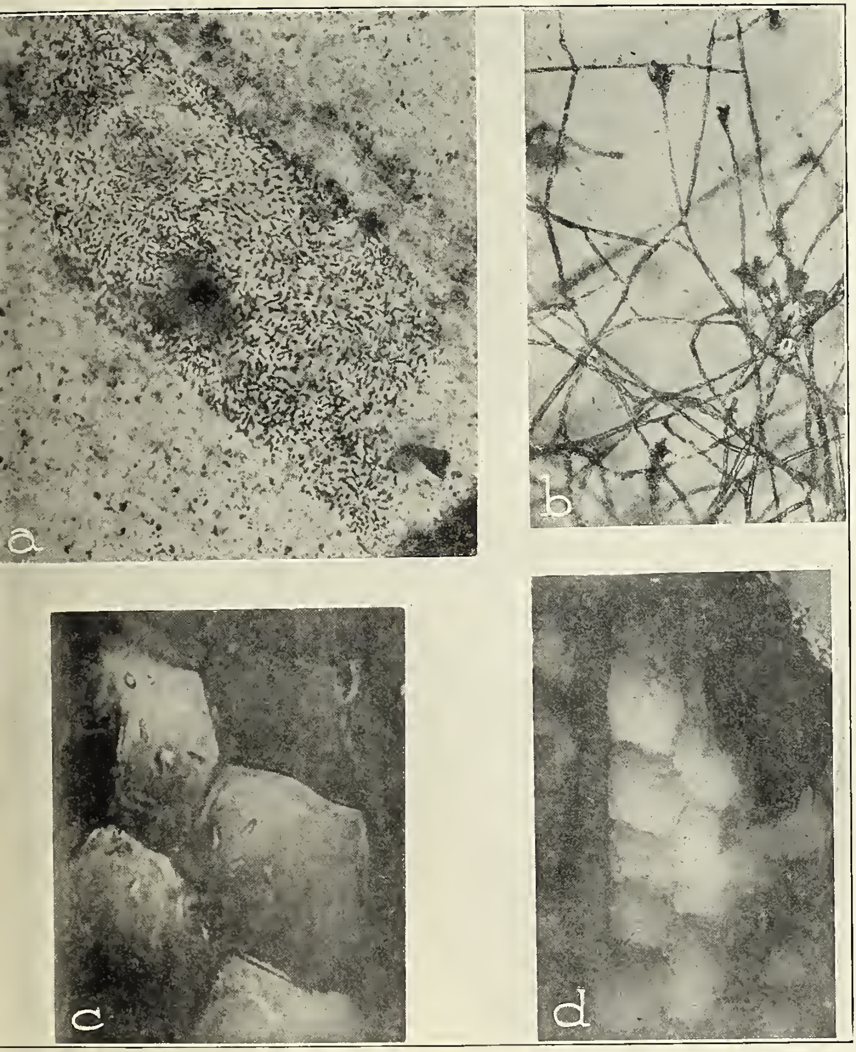


PLATE LXII

PLATE LXIII

PLATE LXIII

BACTERIA IN FOSSIL FISH BONE

The following figures show four stages in the disruption of the osseous lacunae of a Permian fish by the invading bacteria. All figures after Renault.

a. Photomicrograph of a fragment of fossil fish bone from the Autun Basin of France (Permo-Carboniferous), showing the nature in nearly normal bone, of the osseous lacunae, recognized in the black diamond-shaped spots, canaliculi radiating out from the lacunae and vascular channels, seen especially well in the "T"-shaped structure.

b. Photomicrograph of another area of bone showing the beginning of disruption of the lacunae by bacteria. The canaliculi anastomose. The beaded appearance indicates the presence of bacteria in the canaliculi.

c. A further stage of disruption at a higher magnification.

d. The form of the lacunae in this area is almost completely obliterated and the channels in the bone are packed full of Micrococci.

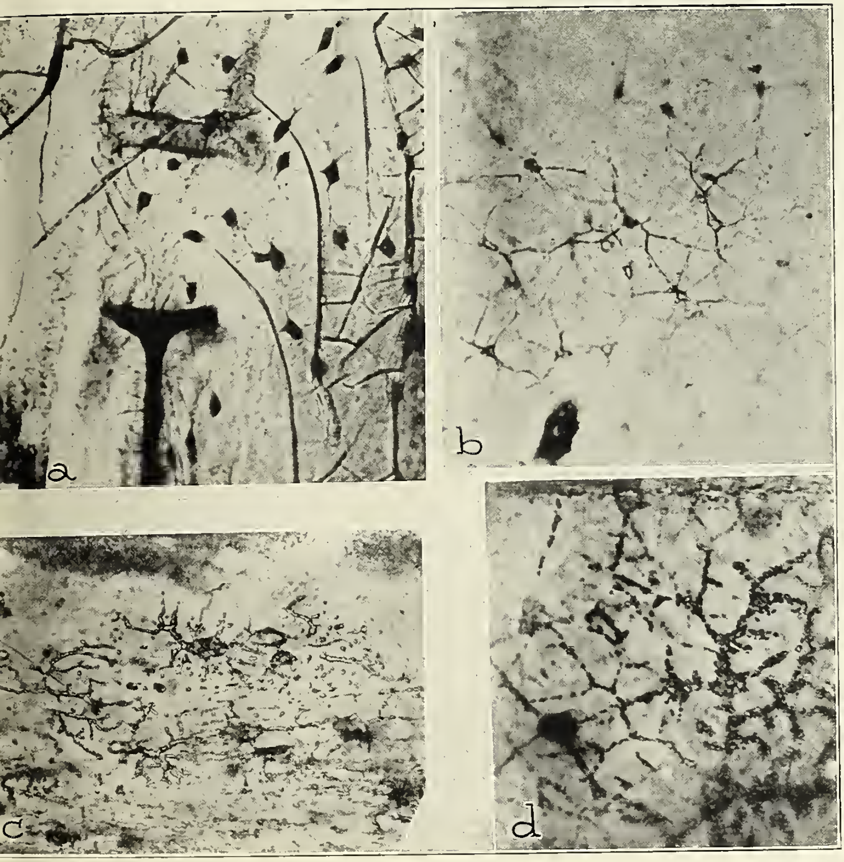


Plate LXIII

PLATE LXIV

PLATE LXIV

EVIDENCES OF BACTERIA IN FOSSIL BONE

a. Bothriolepis canadensis-lacunae in the carapace which have been invaded by bacteria. Devonian, Canada. X 500. The lacunae may be recognized as the long, dark, vertical, spindle-shaped bodies, of which there are several in the photo-micrograph.

b. Pliocene elephant tusk, edge of dentine, showing in the black lines the paths of entrance of bacteria, similar to the invasion of bacteria in cases of dental caries. The invaded dentinal tubules are black. Nebraska. X 300.

c. Coccosteus acadianus—Devonian, Scotland, showing vascular opening and lacunae invaded by bacteria and thread mould. X 500. The vascular opening in the right lower corner may be regarded as a primitive Haversian canal since the surrounding lacunae are arranged in a more or less definite lamellar fashion around it.

d. Articular surface of a dinosaur vertebra, showing lacunae distorted by the resence of bacteria. Como Beds, Wyoming. X 500.

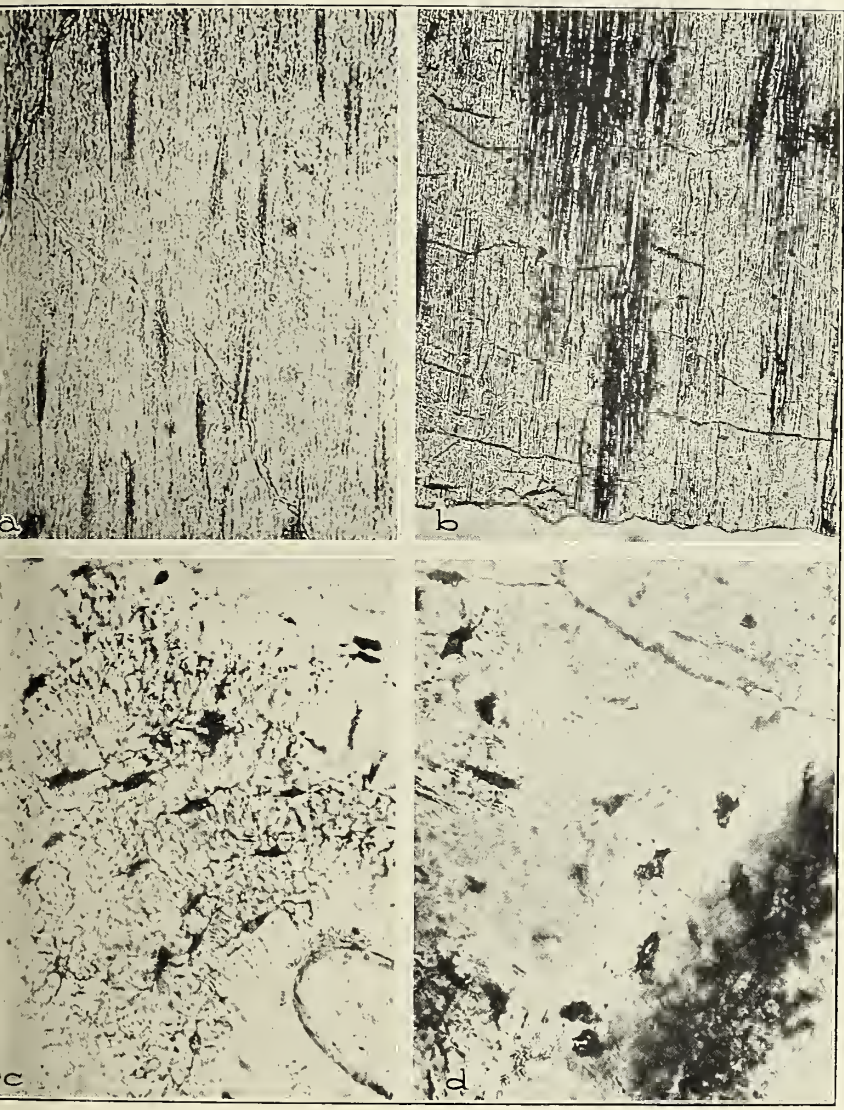


PLATE LXIV

PLATE LXV

PLATE LXV

MICROSCOPIC STRUCTURE OF A PERMIAN COPROLITE

a. Photomicrograph of a coprolite from Texas showing layers of material and folds representing rugae of rectum. X 100.

b. Coprolite of some fish? from the Permian of Texas to show nature of material in which fossil bacteria are frequently found. X 200.

c. The light bar is a spicule of bone in a coprolite from the Permian of Texas—the matrix is dark—the lacunae in the bone are distorted with bacteria. X 200.

d. Area of bone spicule in coprolite from Permian of Texas showing distortion due to presence of bacteria in canaliculi. X 500. Bacteria and groups of bacteria may be detected in the minute rounded bodies seen along the finer ramifications of the canaliculi.

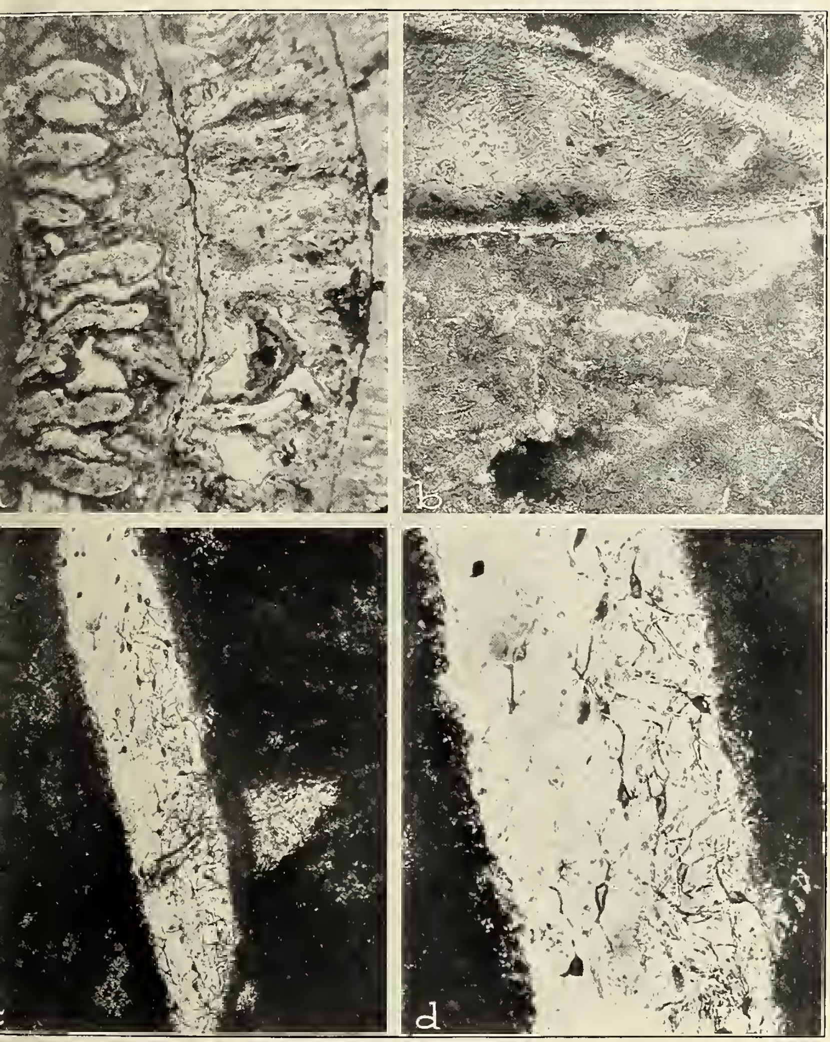


Plate LXV

CHAPTER X

OPISTHOTONOS AND ALLIED PHENOMENA AMONG FOSSIL VERTEBRATES

Frequency of opisthotonos among fossil skeletons. Opisthotonos among pterodactyls. The opisthotonic attitude among ancient birds and dinosaurs. Pleurothotonos. Phenomena among fossil fishes. Opisthotonos in man. Phenomena as manifestations of disease. Summary. Descriptions of Figure 27 and Plates LXVI–LXVIII illustrating Chapter X. Figure 27 and Plates LXVI–LXVIII.

It is a well known fact in modern medicine that the attitudes known as opisthotonos,[1] pleurothotonos, emprosthotonos and allied phenomena are indications of a severe spastic reaction due to the poisoning of the central nervous system either by bacterial poisons, mineral poisons or other toxins which when liberated in the blood attack the brain and spinal cord. The phenomenon of opisthotonos is the more commonly seen and is frequently met with in man and mammals in strychnine poisoning, less strongly in mercurial poisoning. Many animals at death present the opisthotonic attitude[2] which may or may not be the result of a diseased condition but certainly represents a tonic spasm. The phenomenon is not confined to the vertebrates but is evident in such lowly organisms as the opisthobranchiate molluscs where it is induced by effects similar to those which produce the position in higher animals. A close scrutiny of recent animals under the effects of poison and disease would doubtless result in a discovery of its widespread con-

[1] This chapter appeared, with the same title, as an essay in the American Naturalist Vol. 52, no. 620–621, pp. 384–394, Figs. 1–8, 1918 as the third of my "Studies in Paleopathology." It is here elaborated and corrected in accordance with the abundant criticism which that essay produced. The field of opinion is equally divided; the medical men contending that the attitudes of the fossil skeletons exhibit evidences of a tetanic spasm, while many paleontologists fail to see any such effect manifested. In view of this division of opinion it is thought worth while to present the entire problem here in complete form.

[2] Definitions of the term "opisthotonos" differ. Two are given by the Century Dictionary: "A disease in which the limbs are drawn back"; "A tonic spasm in which the body is bent backward," neither of which conforms to medical usage which is best expressed by Stedman's definition: "A tetanic spasm in which the spine and extremeties are bent with convexity forward, the body resting on the head and heels." The term is also used as a name for the attitude of the body which is the result of a spasm, in which case it cannot be regarded as a disease, but as a manifestation of disease.

dition. Such a distribution among modern animals from molluscs to man indicates a fundamental reaction to which the fossil vertebrates need be no exception. Certainly it will be interesting, in searching among the fossil animals for evidences of disease, to compare as far as possible the attitudes of ancient and recent animals with respect to this question of cerebrospinal toxins.

FREQUENCY OF OPISTHOTONOS AMONG FOSSIL VERTEBRATES

Every student of the fossil vertebrates who is fortunate enough to collect a number of complete or approximately complete skeletons of ancient animals is almost sure to be impressed with the frequency of the peculiar curve (Plate LXVII) to the backwardly bent neck and the rigid appearance of the limbs, if these members are preserved in anything like the position assumed by the animals at death. Right here, however, is a most critical point in the entire subject, since we cannot always be sure that the skeleton *is* in a position assumed at death. Unless care is taken to assure onesself of this point the entire subject may be vitiated. So many factors enter into the fossilization of a vertebrate skeleton, and lying unprotected the body is subject to so many accidents before fossilization sets in that great care must be exercised in defining an opisthotonic attitude. It may conceivably be due to the action of water currents, to the effects of carnivorous animals, to shiftings of position due to a change of location or to a variety of causes which reflection may perceive to be possible. In such cases, however, some parts of the body are sure to show the effects of such a disturbance and the evidence checked up. A still more important factor, since such a comparison is necessarily made on published illustrations and descriptions, is to be seen in the shiftings of the fossil bones in the museum preparation of the specimen for exhibit. The position may be modified to suit a certain place in an exhibit or to fit a certain panel. There are however a great number of vertebrate skeletons known in a fossil condition whose positions we are assured have not suffered a change since the interment of the body; such skeletons are commonly seen in aquatic deposits, such as the prolific Solenhofen slates (Plate LXVIII, b and c), and the Triassic slates of Connecticut, wherein we feel confident that the conditions represented are indications of what took place when death occurred. It is on this latter type of evidence that much of the discussion of this chapter is based. The opisthotonic attitude is especially common among fossil vertebrates, though examples of

leurothotonos are not unknown. Emprosthotonos has not been seen, o far as I am aware.

The beautiful skeletons of the small, delicate-limbed, lower Miocene amel, *Stenomylus* (Plate LXVII, b) numbers of which have been obained from a single hill (Fig. 27) in western Nebraska, often show an pisthotonic attitude. *Stenomylus* was an extremely slender, cursorial reature; the head rather small and rounded, the neck long and light. These graceful little camels had a brief career which ended in the lower Miocene. Among a series of skeletons, in the collection of which I had he pleasure of assisting, three showed an opisthotonic attitude, one trongly, and two moderately so, as to the cervicals and anterior dorals only. The condition rarely involved the posterior dorsals and umbars. The phenomenon has also been noted by other collectors in he same quarry and the beautiful little skeleton figured (Plate LXVII,) at present in the Carnegie Museum at Pittsburgh is from that deosit.

Opisthotonos is a fairly common condition among the carnivorous linosaurs, except in those cases where the skeletons lie on the belly or ack; positions which these long-limbed, small-bodied reptiles seldom ccupy. The primitive reptiles, the Pelycosauria, from the Permian of Texas often indicate interesting opisthotonic phenomena, showing a trong reaction along the entire vertebral column, save the free part of he tail.

Williston[3] in describing the remains of *Cimoliasaurus snowii*, a longecked reptile from the chalk cliffs of Kansas, says:

> The specimen comprises the skull and twenty-eight cervical vertebrae, all ttached and with their relative positions but little disturbed. They lie upon the ght side, with the usual opisthotonic curve to the neck, and are all laterally comressed.

The attitude is abundantly represented among fossils and its signifiance is suggested to be the result of spastic distress at or shortly bere the death of the animal.

OPISTHOTONOS AMONG PTERODACTYLS

Many of the beautifully complete skeletons (Plate LVII, c) of the mall winged reptiles known as pterodactyls, such as *Pterodactylus ngirostris*, *P. brevirostris*, *P. elegans* and many other species which have een described during the early part of the last century from the litho-

[3] S. W. Williston: A new Plesiosaur from the Niobrara Cretaceous of Kansas. Tr. Kans. cad. Sci., 1890, p. 1.

graphic slates of Aichstädt by Goldfuss, Cuvier, Wagner and Soemmering, exhibit a marked opisthotonic curve to the neck and a more rigid appearance to the skeleton as a whole than is common among the specimens of these remarkably volant reptiles. *Pterodactylus longirostris* Cuvier shows in one specimen the jaw gaping widely as if trismus was not an accompaniment of the opisthotonos, such as is usually the case in recent examples of tetanus, or else the jaw was secondarily moved by the action of the water after the dissolution of the muscles. Other pterodactyls, such as *Pterodactylus scolopaciceps*, *P. longicollum* and others described by Plieninger[4] from the Jurassic of Swabia show no indication of spastic distress. It is thus seen that the attitude, while common, is not an universal one among the flying reptiles. Some of the more acute attitudes may indicate a cerebro-spinal infection.

THE OPISTHOTONIC ATTITUDE AMONG ANCIENT BIRDS AND DINOSAURS

The toothed bird (Plate LXVIII, b) of the genus *Archaeopteryx*, of which several specimens are known from the lithographic slates of Bavaria and which are commonly figured in the text-books of geology, zoology and paleontology, all exhibit a pronounced opisthotonos. The position may be slightly exaggerated in the slender-necked vertebrates having a relatively heavy head which may pull the neck backwards. Although the weight of the head may have added to the curve of the backwardly bent neck the position is none the less an opisthotonic one, indicating an acute spastic distress. It is thus rendered possible that this well known form of curious reptilian bird may have died of cerebro-spinal poisoning.

The skeleton of the small dinosaur, about the size of a common chicken, described from the lithographic (Upper Jurassic) slates of Jachenhausen, Bavaria and known as *Compsognathus longipes*[5] Wagner (Figure c, Plate LXVIII) exhibits an unusually clear case of opisthotonos; the skull lying far back over the pelvis, the tail thrown sharply up and the toes of one hind foot strongly appressed. Abel[6] offers an entirely different interpretation for the attitute of the animal when he says:

[4] Felix Plieninger: Die Pterosaurier der Juraformation Schwabens. Paleontographica liii, 210–313, 6 pls. 1907.

[5] F. von Nopsca: Neues ueber Compsognathus. N. J. f. Mineral. Geol. u. Paleon. Beilageband, xvi, 1903, 476.

[6] O. Abel: Die Stämme der Wirbeltiere, 1919, p. 582.

The animal's skull and neck are drawn far back over the back and the body was lready far decomposed when it was washed into the lagoon of Jachenhausen. This novement caused slight markings to appear in the soft mud as may be seen on the ight side of the photograph. In the body cavity, not visible in the figure, are the vident remains of a reptile which had been devoured by the *Compsognathus;* these emains having previously been interpreted as embryonic in nature.

t may well be in this case, as suggested by Dean, we are "searching too ar afield" in ascribing the position to disease; but, on the other hand wish to remind my readers that in interpreting ancient phenomena ny opinion must have evidence to support it.

The most striking representation of opisthotonos among the dino-aurs, we may even say among extinct vertebrates, is that seen in the re-nains of the small cursorial dinosaur *Struthiomimus altus* (Figure a, Plate LXVII) described by Osborn[7] from the Belly River series of Alberta. The skeleton of this interesting dinosaur is mounted in a panel where the skeletal parts are placed approximately as found, hough I am told that the limbs were shifted somewhat. The attitude of the body is typically that of the opisthotonos; the jaws exhibiting rismus, with the head thrown sharply back over the sacrum, the tail hrown sharply up and the foot strongly contracted with the toes ap-pressed. The whole attitude of the body strongly suggests some severe pastic distress. The animal may have been a plant feeder and its leath and spastic distress due to feeding on some poisonous plant, such s today produce tetanic spasms in animals. It may have suffered leath from a severe cerebro-spinal infection; but, whatever the cause f its death, the attitude of the fossilized skeleton strongly suggests the ffects of disease. We are not however justified in placing, on such ncertain evidence, the antiquity of either tetanus or the bacillus of etanus back so far in geological time. Opisthotonos, as seen in fossil ertebrates, may be regarded as the result of disease only in such xaggerated cases as shown by this interesting and graceful dinosaur rom the Cretaceous of Alberta.

PLEUROTHOTONOS

The correlative phenomenon, pleurothotonos, is less common mong the higher vertebrates, that is the groups above the Amphibia, ut it is not uncommonly met with in the fishes. Emprosthotonos is ntirely unknown among ancient vertebrates. Occasional indications f pleurothotonos among reptiles may be seen on examining the range of

[7] H. F. Osborn: Skeletal Adaptations of Ornitholestes, Struthiomimus, Tyrannosaurus. ull. Amer. Mus. Natl. Hist., xxxv, 733, pl. 24, 1917.

paleontological literature. The attitude in which the large plesiosaur, *Plesiosaurus macrocephalus* (Fig. a, Plate LXVI) collected by Miss Mary Anning from the Lias of Lyme Regis, England, is doubtless the pleurothotonic. The skeleton is figured in Buckland's Bridgewater Treatise (1837) from which the accompanying illustration is taken. It is improbable that the head of this long-necked plesiosaur, heavy as it was, could have been turned into its present attitude by a current of water, since a force sufficiently strong to have moved the heavy head to one side would doubtless have disturbed other portions of the body, and there is no evidence of this in the skeleton.

The remarkable specimen of the ancient crocodile, *Geosaurus gracilis* H. von Meyer, from the upper Jurassic lithographic slates of Eichstädt, Bavaria, described and illustrated by von Ammon, shows a clearly marked instance of pleurothotonos. The body, slightly twisted, is bent into a strong, uniform arc toward the left, the animal having been preserved on its belly. An ancient teleosaur, *Mystriosaurus bollensis* Cuvier, from the upper Lias of Holzmaden in Würtemberg, as preserved in the Senckenberg Museum at Frankfort and figured by Drevermann, likewise shows a condition of pleurothotonos. Another specimen of this species preserved in the United States National Museum presents an opisthotonic attitude.

PHENOMENA AMONG FOSSIL FISHES

The fishes often assume at death and are fossilized in the pleurothotonic attitude. This is clearly indicated in fishes from the Solenhofen slates, such as *Leptolepis sprattiformis*, as figured by Drevermann, Gaudry and others. This attitude is clearly that of fishes attempting to flop out of the soft mud, where they had been cast, back into the water, and an interpretation of pleurothotonos among fossil fishes as an indication of disease must be made with caution.

It is a remarkable fact that the fishes which present this attitude are most often preserved singly. Fishes which are preserved in a mass seldom show instances of distress. The diatomaceous deposits of Miocene age at Lompoc, California, have preserved in one stratum millions upon millions of a small herring, *Xyne grex*, which had doubtless chosen a small bay some four square miles in extent as a spawning ground.[8] The skeletons are all well preserved, the organic part being carbonized into a dark brown substance. They are not crowded but

[8] David Starr Jordan: A Miocene Catastrophe. Natural History, xx, no. 1, pp. 18–22, 1920.

ccur evenly over the entire extent. The evidences show that the shes all died quietly, there being no evidence of distress among the thous-ids of specimens examined. The question of the cause of the death great masses of animals both in recent and ancient times has been scussed by Wiman,[9] though he leaves the subject in an unsatisfactory ate and much remains to be learned regarding this important phe-omenon.

It is not a necessary sequence that all laterally compressed verte-rates assume the pleurothotonic attitude since often ganoid fishes Figure d, Plate LXVIII) especially assume the opisthotonos. The reat majority of fossil fishes which have been described, and which ave been preserved in an approximately complete manner exhibit either of these phenomena. The great series of Triassic fishes from onnecticut seldom exhibit spastic distress. A single specimen of *atopterus gracilis* of those figured by Eastman[10] exhibits the opistho-onos, and a single one, *Ptycholepis marshi*, exhibits pleurothotonos. Of undreds of specimens of fossil fishes described by Agassiz, Smith Voodward, Newberry, and Eastman a very small percentage exhibits igns of spastic distress. A careful study of the great series of more re-ent fishes from the Oligocene shales of Florissant, Colorado, also points o the same conclusion.

OPISTHOTONOS IN MAN

As clinical manifestations of great severity, opisthotonos and the orrelative phenomena pleurothotonos and emprosthotonos (epis-hotonos) have long been well known in human beings as accompanying ertain phases of tetanus,[11] abscesses of the brain, otitis media, cere-rospinal meningitis, strychnine poisoning, and other afflictions in which the toxins affecting the central nervous system are liberated. n these manifestations the muscles of the body, the spine and the ex-remities are strongly flexed. This characteristic attitude of the spasm as been graphically figured (Plate LXVIII, a) by Sir Charles Bell,[12] who describes it as follows:

> I have here given a sketch of the true Opisthotonos, where it is seen that all ie muscles are rigidly contracted, the more powerful flexors prevailing over the

[9] C. Wiman: Ueber die paleontologische Bedeutung des Massensterbens unter den ieren. Paleontologische Zeitschrift, 1, pp. 145–154, 1914.

[10] Ch. R. Eastman: Triassic Fishes of Connecticut.—State of Conn. Geol. and Nat. Hist. urvey, Bull. 18, Hartford, 1911.

[11] Described by Dr. Dyas in Surgical Clinics of North America, 1921.

[12] Sir Charles Bell: Anatomy of the Expressions. London.

extensors. Were the painter to represent every circumstance faithfully, the effect might be too painful, and something must be left to his taste and imagination.

An interesting case of opisthotonos in a fetus in utero has been described by Falls[13] and the attitude is commonly seen in diseases of children.

PHENOMENA AS MANIFESTATIONS OF DISEASE

It is a matter of great interest to find the same phenomena among fossil animals which are commonly seen in man and the recent animals. The phenomena under discussion are extremely common among modern vertebrates of all classes, and they are so commonly seen in medical laboratories as to be well known to medical students. Often cats inoculated with cerebrospinal meningitis die during the night and are fixed by the *rigor mortis* in the opisthotonic attitude.[14] This fact may explain the positions in which fossil vertebrates are often found. That is they died in opisthotonos, were fixed by the *rigor mortis* and fossilized without being shifted. It seems unnecessary to assume a shifting in all cases as Dean[15] has suggested. One may have been as true as the other. Many of the attitudes assumed by fossil animals may be due to the spasm usually incident to death,[16] the Todeskampf of the Germans, or, in some cases, to accidental shifting of a part of the body after death. Many of the fossil vertebrates whose skeletons are found in anything like a complete state of preservation do not show these manifestations. It is on the whole unusual for the vertebrates to show opisthotonos or pleurothotonos, and the phenomena are more common in the slender necked vertebrates. It is possible that some of the animals whose skeletons are preserved in these attitudes had suffered death from diseases similar to tetanus, or cerebrospinal meningitis, the attitude being produced by the spasm incident to such a disease.

The skeleton of *Mesosaurus brasiliensis* from the Permian of Brazil[17] exhibits a slight degree of opisthotonos such as is common in the death struggle of modern vertebrates. Likewise the skeleton of the plesiosaur, *Plesiosaurus Guilelmi*, described by Fraas[18] from the Posidonienschiefer

[13] F. H. Falls: Opisthotonos Feti. Surg. Gynec. & Obstret., Chicago, 1917, 65–67, 1 fig.

[14] Roy L. Moodie: Opisthotonos. Science, N.S., vol. 50, no. 1290, 275–276, 1919.

[15] Bashford Dean: Dr. Moodie's Opisthotonos. Science, N.S., xlix, 357, 1919.

[16] What did Fossils die of? Literary Digest, May 31, 1919.

[17] J. H. McGregor: Mesosaurus brasiliensis from the Permian of Brazil. Commissao de Estudos das Minas, etc., pl. iv, 1908.

[18] Eberhard Fraas: Pleisosaurier aus dem oberen Lias von Holzmaden. Plaeontographica, lvii, pl. vi, viii. 1910.

o Holzmaden, Germany, exhibits a slight degree of opisthotonos, while te gigantic *Thaumatosaurus victor* is preserved in a perfectly normal atitude. There can be, I think, little doubt that many of these attudes, where slight, may be explained as phenomena accompanying te death struggle, but it seems extremely improbable that all of them cn be explained in this basis. Certainly it is not true that all vertebates whose skeletons are fossilized exhibit indications of such spasms. hile complete skeletal remains are relatively rare, yet there is a sufient number preserved in the many museums throughout the world, te descriptions of which are accessible to all, to determine the relative equency of the positions.

Perhaps no deposit yielding fossil vertebrates has furnished so any beautifully complete skeletons of reptiles as have the Eocene deosits in the basin of the Rhone River which have been described by ortet.[19] A careful study of his monograph shows that only four, *lligatorium Meyeri* (Pl. x), two specimens of *Alligatorellum Beaumonti* Pl. xi), and *Crocodileimus robustus* (Pl. ix), exhibit any degree of the oisthotonic attitude. Only one, *Pleurosaurus Goldfussi*, (Pl. vii) exbits the pleurothotonos. The majority of the remaining skeletons gured show no spastic distress whatever. Though we may say that oisthotonos and pleurothotonos are common they are rather the unsual than the usual state of affairs.

The two dinosaurs, *Struthiomimus altus* and *Compsognathus longipes*, any specimens of small pterodactyls and the toothed bird, *Archeopryx*, exhibit such a marked opisthotonic attitude as to lead one to infer ome cerebrospinal or other intracranial infection which would have een easily possible in the poorly protected brain case of these early ertebrates. It requires but a glance at the nature of the brain case of ie early vertebrates to see how poorly protected the cerebrospinal aces were. Ingress of infecting bacteria may have been through any f the numerous nerve or vascular foramina, through the thin cancelus walls separating the brain case from the sphenoidal sinus, or irough the anterior end of the brain case which was often protected nly by a membranous covering, by cartilage, or by a very thin bony late. The presence of infecting bacteria has been well established and dealt with in Chapter IX.

[19] L. C. Lortet: Les Reptiles du Bassin du Rhône. Archives. d. Mus. d'Hist. nat. de yon, v, 3–139, 12 pls., 1892.

SUMMARY

The significance of the above facts in a discussion of early evidences of disease will be apparent to all, and it was in hopes of shedding light on the antiquity of cerebrospinal infections, as well as to make a comparative study of the attitudes of fossil vertebrates, that the above comparisons are made. In the light of the above evidences it seems probable that some of the instances of opisthotonos and pleurothotonos among fossil vertebrates may be due to acute cerebrospinal infections the petrified skeletons exhibiting trismus, rigidity of the limbs, and the peculiar backward curvature of the vertebral column so common today as clinical manifestations of spastic distress. This is especially probable in the cases where the skeletons exhibit such marked evidences of tetanic spasms as do many of those described above. It may then be said that opisthotonos and allied phenomena as seen in the skeletons of fossil vertebrates indicate disease only in those exaggerated instances of the spasm. Not all vertebrates preserved in opisthotonos are necessarily regarded as victims of cerebrospinal disease but many of them suggest a strong neuro-toxic condition and insofar are to be fairly regarded as ancient evidences of disease.

DESCRIPTIONS OF FIGURE 27 AND PLATES LXVI–LXVIII ILLUSTRATING CHAPTER X

FIGURE 27

Stenomylus Hill, Summit of the Oligocene or Lower Miocene, Lower Harriso Beds, Sioux County, Nebraska. Photograph by American Museum of Natura History, 1908. Numerous primitive camel skeletons (Plate LXVII, b) were dis covered in the excavation which extends, interruptedly, on the other side of th hill.

FIGURE 27

PLATE LXVI

PLATE LXVI

PLEUROTHOTONOS

a. The skeleton of *Plesiosaurus macrocephalus*, a marine reptile from the Lias (Jurassic) of Lyme Regis, England. The specimen is preserved in a pleurothotonic attitude. (After Buckland.)

b. Outline of body and impressions of the cartilaginous skeleton of a primitive shark, *Paleospinax priscus* Agassiz, from the Lias of Lyme Regis, England, showing pleurothotonos. (After Dean.)

c. A coprolite from the Permian of Texas.

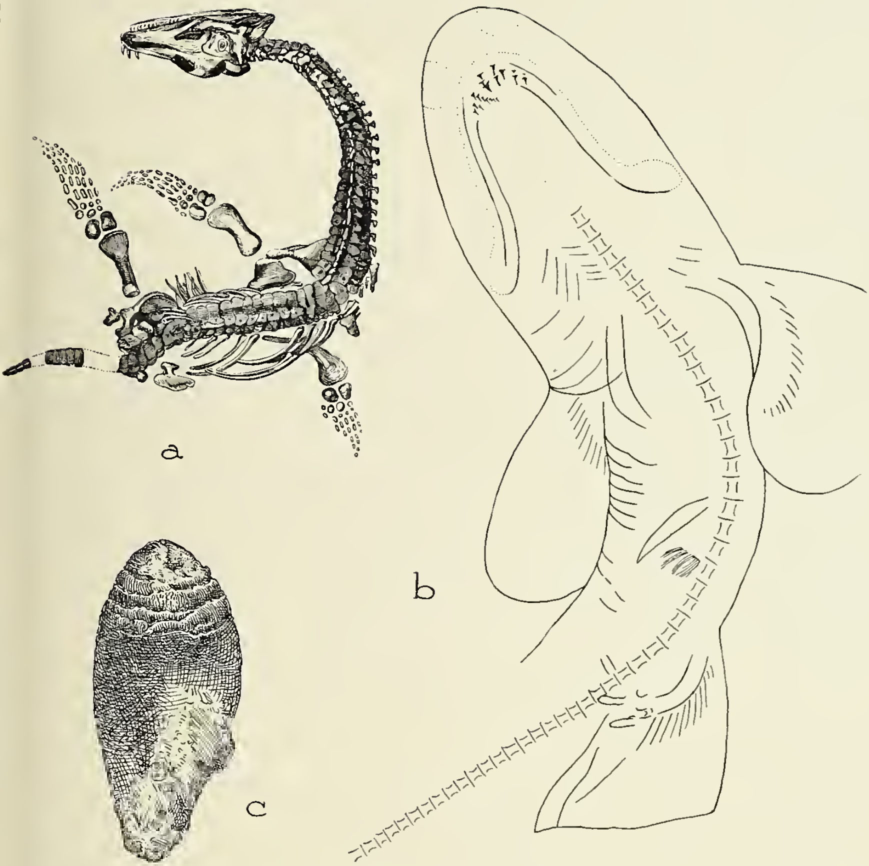


Plate LXVI

PLATE LXVII

PLATE LXVII

OPISTHOTONOS

a. The Skeleton of a cursorial dinosaur, *Struthiomimus altus*, from the Belly River Series, Cretaceous, of Alberta. The skeleton exhibits a strong opisthotonic reaction. Original in the American Museum of Natural History. X 1/30.

b. Skeleton of *Stenomylus*, a camel from the Lower Miocene of Western Nebraska. Collected from the hill shown in the preceding figure 27. It is preserved in a moderate opisthotonic attitude. Original in the Carnegie Museum.

c. The skeleton of *Pterodactylus micronyx* H. von Meyer from the lithographic slates of Eichstädt in Bavaria. The original is in the paleontological collections at Munich. This specimen shows a strong opisthotonos. One-half natural size. (After Broili.)

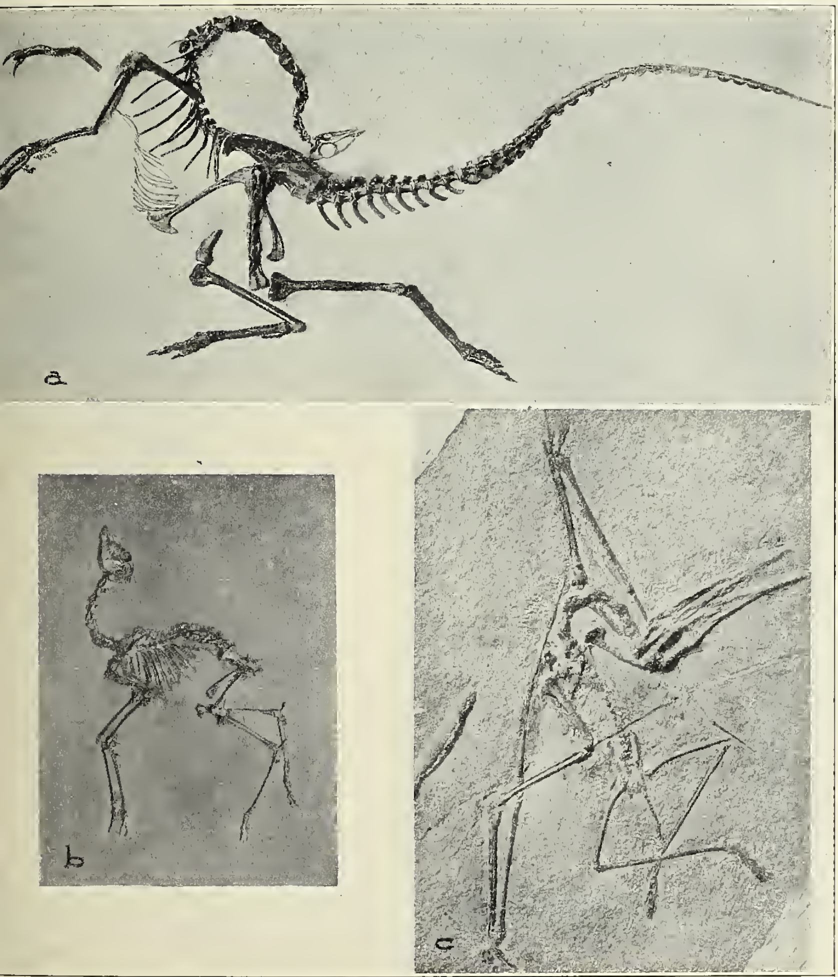


PLATE LXVII

PLATE LXVIII

PLATE LXVIII

OPISTHOTONOS

a. Bell's drawing of a man in opisthotonos.

b. The skeleton and feather impressions of the oldest known bird, Archeopteryx macroura from the lithographic slates of Bavaria, showing a strong opisthotonos. X ¼.

c. The skeleton of the small dinosaur, *Compsognathus longipes* Wagner, from the slates of Kelheim. The position of the head and tail are characteristic expressions of the tetanic spasm. (After Hoernes.)

d. A fossil ganoid fish, *Acanthodes gracilis* Roemer, from the Permian of Klein-Neundorf, Lower Silesia, showing an opisthotonic attitude. (After Hoernes.)

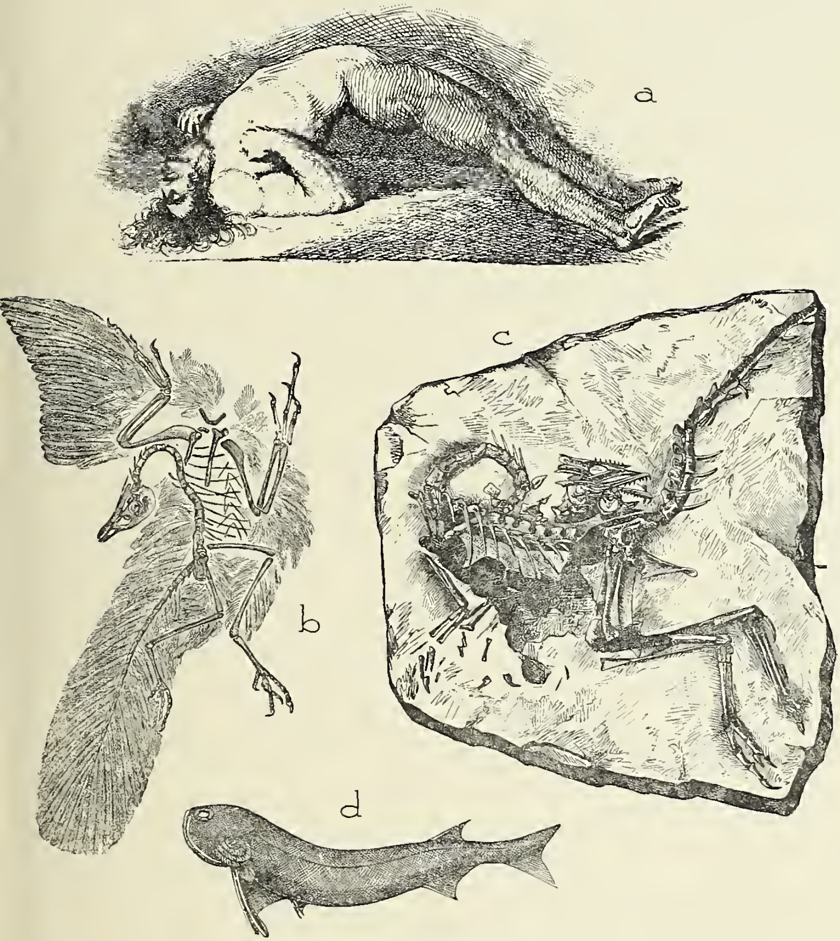


Plate LXVIII

CHAPTER XI

THE EXTINCTION OF RACES

Disease as a factor in extinction. The influence of diseases of the skeleton in the extinction of races. The pathology of the American Mastodon.

The question of extinction is one of the many unsolved problems of iology, although repeated attempts have been made and numerous uggestions offered[1] which bear on the general question. There is, however, at present no accepted view of the cause of extinction in many roups of animals, which have disappeared suddenly, apparently while till in the height of their development; since it is probable that no ne factor explains all cases. Extinction was doubtless due to a great ariety of causes and since disease has been suggested[2] as an important actor it is proper to include here a discussion of this phase of paleo-athology. It was in the hope of adding light on this question that the tudy was first undertaken. The disappearance of the gigantic amhibians, the labyrinthodonts, after a relatively short but vigorous period f existence during which they attained cosmopolitan distribution, heir remains being known from Spitzbergen, Australia, South Africa, urope, Asia and North America, cannot at present be accounted for n any known basis. The possibility of accounting for their disapearance on the basis of diastrophic changes which rendered conditions nfit for their continued existence has been suggested and while this ight account for their extinction in one region it certainly would not o so for all. Why should they be limited to the Triassic in regions as emote as Germany and Wyoming?

Examples almost without end may be taken from the geological istory of the vertebrates showing that numerous groups arose, beame widespread in their distribution and suddenly disappeared. One f the most noted examples is that of the great group of dinosaurs which rose in the Triassic and had a continuous existence as a race for many

[1] C. W. Andrews: Some Suggestions on Extinction. Geol. Mag., Dec., IV, x, no. 463, 1, also C. B. Crampton: Proc. Roy. Phys. Soc., Edinburgh, xiv, 461.

[2] R. S. Lull: Organic Evolution, 1917, pp. 224–228—a general discussion of the problem d various suggestions made.

million years, becoming extinct at the close of the Cretaceous. Many forms of dinosaurs, of course, died out before the race was extinct, and the latest surviving members, huge, spinescent and inoffensive were totally unlike the beginners of the race. Extinction of this group was not a sudden one but was a gradual process and was of great duration. The cause was racial old age and disease may have been a factor. But whether it was also their gigantic size and consequent unwieldiness, or whether it was the introduction of the small mammals which fed on their eggs and young or a change of climate, is uncertain. It may have been a combination of all the factors mentioned.

Osborn[3] has given the factors of extinction among mammals and has reviewed the literature pertaining to this question. Howorth[4] has discussed the disappearance of the various types of Pleistocene elephants, but since the majority of this discussion is foreign to our purpose we refer the reader to the authors mentioned for further details on the question of extinction. All we care to establish is the general problem of extinction and then consider especially the relation of disease, as seen in the ancient pathological lesions, to the extinction of the various groups.

DISEASE AS A FACTOR IN EXTINCTION

The beginnings of disease are intimately associated with parasitism, and parasitism doubtless had an important influence in the extinction of many prehistoric races. Early parasitic conditions must be assumed because there are few evidences of this in the remains at our disposal. We are greatly hampered and limited in our observations on ancient parasitism by the lack of all soft parts. Parasitic lesions on hard parts are rare though it is possible that parasites inhabited their host at an early geological period. We have no way to disprove the presence of infective Sporozoa in the Cambrian or pre-Cambrian. We are limited here to speculations.

It is, however, a noteworthy fact that many groups of animals became extinct before the period when lesions are found in any perceptible numbers. The eurypterids, a group of gigantic arachnids, appeared first in the Cambrian (*Strabops*), had reached their maximum development by the end of the Silurian, and appear in scattered forms until the Carbonic. They had thus largely become extinct before definite pathological lesions, which were associated with diseases, are known. The

[3] H. F. Osborn: The Causes of Extinction of Mammalia. American Naturalist, XL 1906, 769–795, 829–859.

[4] H. H. Howorth: The Mammoth and the Flood, 1887, 155.

rilobites, early crustaceans, were among the first of the higher forms o develop. They thrived continuously for many geological periods nd ended their career with the Permian. Other instances might be ited but these will suffice to show that disease has not always been n important factor, since it was almost wholly absent during the eriods of the early and middle Paleozoic.

Osborn has called attention to the part disease may have played ı the extinction of the mammals, basing his suggestions on the preva-ənce of certain diseases among modern mammals, such as the Texas ever, 'rinderpest,' biliary fever and the diseases transmitted by biting ısects, especially the tsetse fly. He did not, however, cite any in-tances in which disease is known to have played a part in the ex-inction of the ancient mammals, and it is not likely that epidemic iseases of which he spoke would leave any impress upon the fossilized keleton.

The presence of several species of tsetse flies (Fig. b, Plate LXIX) f the genus *Glossina* during the Oligocene is established by the studies f T. D. A. Cockerell[5] on the insects from the Florissant shales of Colorado. This discovery is very suggestive of the possibility of a idespread epidemic of the *nagana* among the ungulates of the arly Tertiary, a million or more years ago. It is of course im-ossible to determine whether or not these flies carried trypanosomes, ut the definite occurrence of the insects in a horizon of the Tertiary ocks is certainly very suggestive of such a possibility, and must be onsidered as an extremely probable cause of extinction, and as an al-ıost certain factor of disease in ancient times. The map (Figure 3) will show how distant from the Colorado region is the region of ıodern trypanosomiasis. If such a disease as the nagana did invade ıe Tertiary herds of horses and other mammals there would be no os-ous lesions left to tell the tale, since this disease is essentially an af-ction of the blood, and blood-forming organs, spleen, liver, and bone arrow[6] and does not attack the bones. Trypanosomiasis in modern ıttle, mules, and horses of the Sudan,[7] South and Central Africa, outh America and southern Asia is due to the presence in the blood ıd blood-forming organs of *Trypanosoma brucei*, *T. nanum*, T.

[5] New species of North American fossil Bettles, Cockroaches, and Tsetse Flies. Proc. S. Nat. Mus., Wash., 1918, liv, 301–311, pl. 55.

[6] Frederick A. Baldwin: The pathological Anatomy of experimental Nagana. J. Infect. s., i, 544–550, 1904.

[7] Andrew Balfour: Trypanosomiasis in the Anglo-Egyptian Sudan. 2nd Rpt. Wellcome search Lab., Gordon Memorial College, Khartoum, 1906, 113–172.

dimorpha, carried from the sick to the well by several species of tsetse flies, notably *Glossina morsitans* and *G. longipennis*.

THE INFLUENCE OF DISEASES OF THE SKELETON IN THE EXTINCTION OF RACES

The lesions on fossil bones, so far studied, are the results of accidents, or of infections, and none of them are extensive. It is improbable that any of the lesions so far studied were so severe that the life of the race was endangered, and only in a few instances may we say that the life of the individual was sacrificed to the disease. It is extremely doubtful if lesions of the nature of most of those seen in a fossil condition are ever fatal. They probably resulted in the loss of usefulness of the member afflicted and no other result was noticeable.

The present results of the study of fossil pathology indicate the early appearance in geological time and widespread distribution of disease of many kinds, but none of them, so far as the lesions may be interpreted, appear to have been sufficiently severe to have played a part in the extinction of any of the known races of vertebrates. They are to be regarded rather as chronic, infectious, or constitutional diseases which may have played a part in extinction, but there must have been some other and more powerful factor which is at present unknown.

PATHOLOGY OF THE AMERICAN MASTODON

We may cite, as an example of the influence diseases, evidenced on the skeletal remains, may have had on extinction, the pathology of the American Mastodon. This form of elephant was exceedingly abundant in North America during the Pleistocene, during which period it became extinct. The causes of its extinction are problematical, since related species have survived in Asia and Africa. The pathology has already been discussed in a detailed fashion in the preceding pages, and it will suffice here to review the lesions as they are known. Skeletal remains in abundance indicate that the Mastodon was on the whole a healthy animal.

Dental caries has been detected in various specimens of elephant fossil molars. Although thousands of fossil mammals have been collected extremely few of them show evidences of dental caries, and in none are the evidences so clear as among the Pleistocene Mastodon. Leidy has described an example of advanced dental caries in a tooth from Florida and Hermann has discussed extensively the nature of similar necroses in Pleistocene teeth from Ohio. The fragmentary na-

ıre of the remains renders uncertain whether or not there were meta-
:ases.

A necrotic sinus is seen in the left temporal fossa of a skeleton which of only local significance. This may have been due to an injury. ther injuries are positively indicated in a fractured skull, fractured bs and certain other lesions of a traumatic origin. It seems perfectly :rtain from this evidence that disease indicated by lesions on the :eletal remains could have had no influence whatsoever on the ex- nction of the Mastodon.

CHAPTER XII

PATHOLOGY OF THE EARLY HUMAN RACES

Pathological femur of Pithecanthropus. Pathology of the men of the old stone age (Paleolithic). Neolithic Injuries. Evidences of syphilis among ancient men. Prehistoric trephining. The use of the cautery among Neolithic and later primitive peoples as a cause of skull lesions. The amputation of fingers among primitive races. Descriptions of Figures 28–35 and Plates LXIX–LXXIII illustrating Chapters XI and XII. Figures 28–35 and Plates LXIX–LXXIII.

The remains of the stone age men of Europe occasionally show evidences of disease and injury, and these evidences among the Neolithic and Paleolithic races of western Europe have been studied especially by Raymond (1912), by Le Baron (1881), and mention of sundry other lesions is made by Keith (1916), Manouvrier (1903), Ruffer (1918.1), Baudouin and other students of anthropology. These studies are necessarily based on the remains of human races which occupied European countries, since no representatives of the Neolithic and Paleolithic peoples are to be found in the Western Hemisphere. A discussion of prehistoric trephining is introduced in this chapter since this operation doubtless indicates certain forms of disease among ancient men, and was of itself a traumatism.

PATHOLOGICAL FEMUR OF PITHECANTHROPUS

The oldest well-authenticated skeletal remains of man or man's precursors on earth were found in 1891-2 by Dr. E. Dubois,[1] then a surgeon in the Dutch Army, while engaged in paleontological excavations along the left bank of the Solo River, near Trinil, in the central part of the island of Java. These important remains were described by Dubois. His work was immediately received as one of the greatest contributions to the study of the antiquity of man. A rather extensive literature has grown up around these remains, to which an age of half a million years has been assigned. The interest to us in this curious form

[1] Pithecanthropus erectus, Batavia, 1894, 4°.

is that the left femur, which was found entire, shows marked exostoses indicating the presence of a pathological condition.

Under the leadership of Rudolf Virchow, on December 14th, 1895 there was called a meeting of the Berlin Society of Anthropology and Ethnology to consider especially the remains of *Pithecanthropus erectus* as these elements of man's precursor were called. Attention was called by Dubois, Kollmann and Virchow to the exostoses on the femur. Virchow read a paper (1895.2) in which he showed that the pathological conditions in the extinct form (Figs. *a* and *b*, Plate LXXI) were similar to exostoses in recent human skeletons, and he exhibited examples (Fig. *d*, Plate LXXI) of such diseased bones from the collections of the Berlin Pathological Institute.

PATHOLOGY OF THE MEN OF THE OLD STONE AGE (PALEOLITHIC)

The most famous of the skeletal remains representing early fossil (Upper Paleolithic) man are the portions of a skeleton of an extinct species of man found in a cave in the Neanderthal, in the Rhine province of Prussia, and fully described by Schaafhausen (1858). Some of the skeletal elements show pathological lesions,[2] the proximal end of the left ulna (Fig. c., Plate LXXI) doubtless had suffered fracture of the olecranon, which had healed with a widening of the articular fossa. The left humerus shows signs of injury in consequence of which it doubtless remained much weaker than the right bone. Caries has been said to be evident on the occiput but this has been denied by Schwalbe (1901). Virchow (1872) on the other hand regarded the pathological shortening of the ulna and humerus as indicating rickets, and on account of these deformities no reliance could be placed on the classification of the skeleton. Schwalbe, in restudying the specimen, showed that the form of the bones was typical for the *primigenius* type, a conclusion which is now widely accepted. Virchow diagnosed arthritis deformans on the Neanderthal man and on a Neolithic skeleton from Tanger-Münde.

Sir Auckland Geddes suggests that the Piltdown skull[2a] is pathological, basing his conclusions on the remarkable thickness, coupled with the characteristic outline of the temporal ridge, which can only find their diagnosis in Acromegaly, and that it is to this that the specimen was preserved. These may, however, be due to Paget's disease.

[2] Gorjanovic-Kramberger, 1908. Anomalien und krankhafte Erscheinungen am Skelette des Urmenschen von Krapina. Die Umschau, xii, 623–626.

[2a] J. G. Adami: Medical Contributions to the Study of Evolution, 16, 1918.

NEOLITHIC INJURIES

One of the most interesting cases of injury in early (Neolithic) man i a specimen of a lumbar vertebra showing (Fig. *b*. Plate LXX) a sone arrow point embedded deeply in the visceral surface. The in-vidual was shot through the abdomen, and the arrow must have been ming with terrific force since it penetrated the abdominal wall near the nbilicus, plowed its way through the viscera and embedded itself so mly in the body of the vertebra that it still remains fixed after thous-ads of years. The individual may have died of peritonitis or he may ve died from some other cause, such as hemorrhage, but there is no idication that he lived a great while after the injury, since there is an osence of callus around the wound.

A skeleton of an extinct wild bull, as mounted in the museum at openhagen, shows some rib injuries (Fig. *e*. Plate LXX) inflicted by te stone arrow point of early hunters.

Arrow point injuries are fairly common (Plate LXX) and other ex-aples of the injury are known, and have been especially well de-sribed among the North American aborigines. Wilson[3] writes of a skull th an arrow point in the left squamosal, a pelvic bone pierced by a fnt arrow (Plate LXX) point, a lumbar vertebra penetrated by an rrow of white quartz, from an Indian mound in Dakota. Miller[4] has scribed an early lumbar vertebra pierced by a spearpoint (Plate CII, d) of antler. He has reviewed the cases and illustrated his ob-svation with an excellent photograph of the lumbar vertebra.

Stone age injuries (Plate LXX), both of human beings and wild aimals are well known as may be seen from the following:

> There is no question that the wild ox was hunted by prehistoric man. A skull fm Burwell Fen has a stone weapon buried in its forehead; a skeleton from Vig i Denmark has both fresh and old wound-scars on the ribs and with it were found tee stone spear points; these are but two out of many instances of this kind. Vile thus abundant in the earlier and later Stone ages, it (the wild ox) seems to hve disappeared before the spread of civilization, surviving as a wild animal only i he great forests of central Europe.[5]

In the Neolithic period wounds made by blows from hatchets, ar-rv points and spear points were fairly common and have been widely dcussed[6] and a few figures (Plate LXX) are given which show the

[3] Thomas Wilson: Arrow Wounds. Am. Anthrop., Wash., N. S., iii, 513.

[4] M. G. Miller, 1913. Human Vertebra transfixed by a Spearpoint of Antler. J. Acad. N. Sc., Phila. xvi, pt. 3, 477–480, 1 fig.

[5] W. D. Matthew, 1921. Urus and Bison. Natural History, xxi, 605.

[6] Emile Cartailhac: La France prehistorique d'apres les sepultures et les monuments. Pis, 8vo, 1903.

nature of the injuries. Many of the wounds observed on the skeleta elements from the ancient sepulchres of France are of long standing and show healed margins and often sequestrae, giving some insight into the nature of infection (Plate LXX, d) and suppuration thousands o years ago.

Paul Bartels[7] has described a series of vertebrae comprising the third to sixth thoracic from the later Neolithic evidently exhibiting indications (Plate LXIX, *a*, *c*, *d*) of Pott's disease. This is thus a very ancien indication of tuberculosis, and should be compared with similar conditions found by Hrdlička from the mounds (Plate XCI) of the southern States, and by Ruffer and Elliot Smith (Plate LXXIV) from ancien Egypt. Bartels gives a careful review of anthropological literatur throwing a light on certain diseases of ancient man and has figured radiographs (Plate LXIX, *c*) of his specimens of supposed tuberculosis The specimens show a lordosis and erosion by caries, such as described by Ruffer and Smith, and in these two particulars the disease seems to be tubercular. Whether it is safe to diagnose ancient osseous lesions a due to definite causes is to be determined after more extended studie on such conditions have been made. Bartels' case is an interesting and suggestive one.

Le Baron's thesis[8] is an excellent discussion and tabulation of th lesions of prehistoric man as they were exhibited by the remains of pre historic man in the museums of Broca and Dupuytren.

The author defines the close of the prehistoric period as ending i France about 200 years before the Christian era and on the Africa coast some hundred of years later.

The means he used to diagnose the lesions was simply to study the aspect and configuration and to compare them with the identifie lesions in the pathological museums. He does not find any evidence in fossil men of lesions due to diseases which are unknown today. Th occurrence of syphilis is very uncertain, although it is suggested b certain lesions.

Le Baron classifies the lesions found in the prehistoric human re mains of France and Algeria as follows:

1. Lésions mécaniques
    1. Lesions posthumes, recentes et anciennes.

[7] Archiv für Anthropologie, 1907, pl. xv.

[8] Le Baron, Jules 1881—Lésions osseuses de l'homme préhistorique en France et Algérie. Thèse pour le Doctorat en Médicine présentee et soutenue le vendredi 1er Juil 1881, pp. 1–118.

2. Lésions mécaniques ayant frappe l'homme anciennes vivant.
    I. Lesions par armes de guerre. 36 specimens described.
    II. Lesions dues a un accident. 18 specimens described.
    III. Trepanations. 4 examples.
3. Lesions spontaneés
    Lesions de la tête.
    Lesions des membres.
    Lesions des vertébrés.

His conclusions give an excellent review and summary of this note-orthy contribution. He has been able to show on the basis of the oove study something of the manners and customs of prehistoric en, some details of surgical operations performed by them, as well as exhibit something of the nature of diseases to which they were sub-ct.

He described five metatarsals which had been pierced for suspension, ossibly in the form of a necklace; a scapula sculptured in the form of bird, and a fibula notched by a flint knife. These facts, added to those hich have already been published by various authors, point to the onclusion that prehistoric man had barbarous customs and was ithropophagus. This is nothing extraordinary since cannibalism not rare among primitive peoples today.

Many of the lesions show injuries which indicate that war was uite common among these peoples. Pillage and conquest have for a ng time had an important place in the life of primitive peoples. It notable that most of the injuries were received in the head. They are ows from stones, clubs, axes, arrows, swords etc.

One searches in vain among recent crania for evidences of such merous lesions. It is possible that pathology has been modified by es and customs.

It is remarkable that many of the lesions of other days have be-me matters of history, while other lesions previously unknown have come more and more frequent. Who does not remember the tales the terrible plagues of which historians have given us such touching scriptions? Scurvey, which in previous times had decimated the ps, became less and less frequent. Hygienic conditions tended each y to dispel those maladies which of old had been mistress of the field. philis, on the contrary, relatively rare among ancient peoples, has come a common disease, since transportation has rendered the ming-g of peoples more easy. Many of the tribes of Oceania, exempt m this disease at the beginning of the century, are today victims of s dreadful pest.

A curious operation practised by primitive man is that of trepanation. The method of performing this operation by means of scraping with flint has been explained elsewhere. This was not, however, the the only surgical procedure. They reduced and fixed fractures with great perfection. Among those which Le Baron described there are some which have healed without dressing, such as fractures of the ribs and the lower end of the radius, but there are others which could not have united without intervention of some sort.

Among the 18 cases there are only 3 which have healed badly. Among these defective cases there was noticed a fracture of the femur. The union was very imperfect, but in spite of the great progress made in modern surgery it would be possible to cite recent parallel cases

A résumé of the fractures met by Le Baron among fossil men is as follows: four fractures of the lower end of the radius (Colles' fracture) a fracture of the radius in the upper superior third (poor union); a fracture at the middle of the ulna (good union); a fracture of the lower third of the humerus (good result); a fracture of the humerus below the surgical neck; a fracture of the clavicle (good result); a fracture o the body of the femur (poor result); an intracapsular fracture of th neck of the femur (good union); a fracture of the tibia below the mal leolus (good union, in spite of probable suppuration); a fracture of th superior third of the fibula (satisfactory consolidation, but some callu of both bones has resulted); five fractures of the ribs (good unions) two fractures of the clavicle, with good unions, discovered in a grave b M. Nicaise at Tour-sur-Marne, concludes the list of the known frac tures of the bones of prehistoric men of France and Algeria.

Other maladies. Arthritis has been frequently met with among pre historic bones. Le Baron found more than thirty examples, among ther four synostoses. The animals which inhabited the same regions an possibly at times the same caverns were not more fortunate than th men for their skeletons show numerous traces of arthritides.

Diseases of the jaws are very common with primitive man. Peric stitic cysts and exostoses are not at all rare. Erosions of eight teet seem to indicate syphilitic influence. Other evidences of syphilis ar found in the hyperostosis of a tibia, but the evidence is doubtful an if it is syphilis the occurrence of this disease is quite rare.

Other interesting lesions which have been met with are the follov ing: alteration of the skull due to an ulceration; a scoliosis; sever hyperostoses of the skull; a case of hyperostosis of the tibia due to a

lcer; caries; atrophy of the skull; an unusual exostosis of the con-yle of the jaw; a cancer of the lower jaw.

Paul Raymond in his paper[9] has described and figured in Neolithic ıan of Europe a case of spondylitis deformans, one of arthritis of the nee, congenital luxation of the femur, fracture of the femur with callus, nd syphilis of the humerus and radius.

Raymond reports that all types of fractures are found on pre-istoric bones. He discusses the frequence of arthritis deformans on the ones of these ancient races, attributing this deformation to their ıhabiting caverns, but he failed to note that the ancient Egyptians who id not live in caverns were likewise afflicted with the same disease. n connection with arthritis he finds considerable spondylitis defor-ıans and osteophyte growth. He refers to cases of Neolithic examples f Pott's disease, vertebral tuberculosis, and scoliosis.

His contribution to the origin of syphilis has not attracted much ttention and his evidence is worth considering. He figures a humerus nd radius which bear evidence of lesions resembling those of syphilis. Iowever convincing his figures may be one is withheld from accepting is conclusions outright because he has failed to give the evidence on vhich he has based his statement of the age of the remains. Neo-thic syphilis in Europe may be a possibility but it is so contrary to the ccepted views of the origin and history of this disease that much more omplete data will need to be presented before Neolithic syphilis can be stablished as a fact.

EVIDENCES OF SYPHILIS AMONG ANCIENT MEN

In studying the evidences of syphilis among early human races it is ery important to keep in mind the nature of the fossil bones of extinct nimals which show hypertrophy, hyperostoses and carious roughen-ıg quite similar to the lesions frequently diagnosed among ancient bones s syphilis. Such diagnoses are of uncertain importance, unless backed y further evidence. Virchow called attention to this similarity in his aper on the history of syphilis (1896). He had previously (1895.1) escribed and figured carefully the hypertrophied and roughened adius of a cave bear (Fig. *b*. Plate VIII) which resembles strongly uman bones showing lesions ascribed to syphilis in the papers of)rton (1905), Raymond (1912) and Eaton (1916). Virchow applied he term "Höhlengicht" or cave-gout to some of the lesions of the cave

[9] Raymond, Paul 1912—Les Maladies de nos ancêtres a l'âge de la Pierre. Aesculape, ol. 2, pp. 121–123, with 6 figs.

bears, referring especially to the spondylitis deformans and other arthritic lesions seen in cave bears of the Pleistocene. It may be safely said that syphilis has not been definitely shown to exist anywhere in fossil or subfossil bones. The earliest accepted date at which syphilis is definitely known is 1495, when the sailors of Columbus carried it to Naples.

The tubercle of Carabelli, described by the noted dentist of Vienna[10] as a "*Tuberculum anomalus*" occurs on the anterior, lingual surface of the first, second, and frequently the third upper molars. Since aberrant cusps may develop at any one of three places along the lingual margin of the molar, there has often been some confusion in the proper identification of the Tubercle of Carabelli. The presence of this cusp is often said to be indicative of congenital syphilis, and Jeanselme (1918) related that treatment for congenital syphilis is often instituted on the basis of the presence of this cusp. The fact that this cusp is more frequently present in children than in adults and in primitive races more frequently than in civilized races, and its wide spread occurrence in Neolithic and Paleolithic dentitions calls for its discussion in this place. Gorjanovic-Kramberger[11] says that the tubercle occurs in nearly all of the first and second upper molars of the fossil human skeletons from Krapina, which represent a race of men who lived about 75,000 years ago. He has given an excellent photograph of the tubercle of Carabelli on the molars of fossil man, and for comparison similar cusps on the molars of a native of Java are shown. Batujeff (1896) shows that the presence of this cusp in the primitive races of man and many genera of apes is of wide distribution. A careful study of the upper molars of fossil primates might reveal the presence of similar cusps.

Since the tubercle of Carabelli has such an ancient history, being demonstrable many, many thousands of years prior to our knowledge of the occurrence of syphilis, it is difficult to see that it has any significance in a diagnosis of disease. Especially is this a probable solution since Hutchinson's teeth, so long regarded as diagnostic of congenital syphilis, have been recently shown to be due to faulty nutrition. The tubercle of Carabelli may be regarded as the persistence of an ancient character, and while it may be hereditary, it certainly can have nothing to do with syphilis. The following table, adopted from Osborn, shows the time relations of these ancient human remains.

[10] Carabelli, George C. 1842—Systematisches Handbuch der Zahnheilkunde, Bd. II, Anatomie des Mundes, p. 107.

[11] Gorjanovic-Kramberger, 1907—Die Kronen und Wurzeln der Mahlzähne des Homo primigenius und ihre genetische Bedeutung. Anat. Anz., Jena, xxxi, 118–120, fig. 13.

eological Period	Stone Cultures and Cold Periods	Division	Human Types	Animal types
		Prehistoric	Modern races	Recent faunas
RECENT uration, 25,000 ears	Bronze age Neolithic	Neolithic	Ancestors of modern man	Reindeer periods
	Azilian-Tardenoisan Magdalenian Solutrean Aurignacian 25,000 yrs.*	UPPER PALEOLITHIC	Grenelle Crô-Magnon Grimaldi Neanderthal " " "	Ancient horses Elephants, hippotami, woolly rhinoceros, hairy mammoth, lions and bears
	Mousterian 50,000 yrs.		(Krapina)	
	Acheulean 75,000 yrs.	LOWER PALEOLITHIC		
	Chellean 100,000 yrs.			
			Piltdown Man	
	Prechellean 125,000 yrs.			
LEISTOCENE duration 500,000 yrs.	Third Glacial Period 150,000–200,000 yrs.			
	Second Interglacial Period. 200,000–350,000 yrs.		Heidelberg Man	
	Second Glacial Period. 350,000–400,000 yrs.			Cave bears and their associates
	First Interglacial Period. 425,000–450,000 years.			
	First Glacial Period 475,000–500,000 yrs.			Saber toothed cats. Ancient horses and elephants. Extinct mammals.
			Man's precursor Pithecanthropus (Trinil)	
IOCENE uration 00,000 yrs.	525,000 yrs. from the close of the Pliocene to the opening of the Recent			Extinct mammals

* This indicates 25,000 yrs. prior to the Recent period, which has itself persisted for ,000 yrs.

PREHISTORIC TREPHINING[12]

Trepanning (Plate LXXII) or trephining the skull was an operation frequently performed 10,000 years ago in Neolithic times, especially in western Europe[13] and in Bohemia.[14]

Evidences of its practice in early times are also found in Bolivia,[15] Peru,[16] North America,[17] Mexico (Figure 29) and Central America, although none of these latter evidences are of Neolithic age. There is no evidence of the operation being performed by either the Hindoos or Chinese, nor among the Greeks and Romans. A single doubtful example is known from Egypt. Some trepanned skulls have been discovered in Gaul, belonging to an epoch corresponding to that of Roman civilization.

The contemporary hill-tribes of Daghestan, the natives of Tahiti, the Polynesians, and Loyalty Islanders, the Kabyl tribes (but not the Arabs or Negroes in contact with them) Montenegrins, and the Aymara

[12] Trephining is discussed here because the operation indicates some forms of disease or injury, and because the operation itself was a traumatism, often of a very serious and frequently fatal nature. The present discussion is not an exhaustive account of the subject but the majority of the literature has been seen and is referred to in this chapter.

[13] Neolithic trephining has been discussed by a number of writers, the subject being apparently initiated by Pruniéres: Deux nouveaux cas de trépanation chirurgicale néolithique. Bull. Soc. d'anthrop. de Paris, 1876, 551, although there are a number of papers at about the same time, such as Chauvet: Trépanations préhistoriques. Bull. Soc. d'Anthrop. de Paris, 1877, 12; Paul Broca: Sur la trépanation du crâne, et les amulettes craniennes á l'époque néolithique, Paris, 80, also by the same: Sur l'âge des sujets soumis á la trépanation chirurgicale néolithique, Bull. Soc. d'anthrop. de Paris, 1876, 572, and Congrés d'anthrop. et d'archeol. préhist., Budapest, 1876, 101–192, as well as De Mortillet: Trépanation préhistorique. Bull. Soc. d'anthrop. de Paris, 1882, v, iii ser. 143–146.

There are interesting reviews by many authors, of which the most complete is H. Tillmans: Ueber praehistorische Chirurgie. Archiv f. klin. Chirur., xxviii, 775–802, 1 pl. Other reviews by Keith (1916, p. 20), Fletcher (1882), Manouvrier (1903), Derry (1914), Ruffer (1918), Freeman (1918) should be referred to in this connection. The following account of the subject is based on the above essays.

[14] B. Dudik: Ueber trepanirte Cranien im Beinhause zu Sedlec (Böhmen). Zeit. f. Ethnol., 1878, 227.

[15] A. F. Bandelier: Aboriginal Trephining in Bolivia. Am. Anthrop. N.S., vi, 440–446, 1904.

[16] E. George Squiers: Incidents of Travel and Exploration in the land of the Incas, New York, 1877, 456. The skull brought back by Squiers is also described in the unique publication of the Journal of the Anthropological Institute of New York for 1871–72, vol. 1, no. 1 (all ever published), as well as in the report by M. A. Muniz and W. J. McGee: Primitive Trephining in Peru, 16th Ann. Rep. Bur. Am. Ethnology, Wash., 1897, pl. III, and a line drawing of it is shown in a figure. The skull was shown to the Paris Society of Anthropology, but is now in the American Museum of Natural History. See Plate CIX, *d*.

[17] Henry Gillman: Certain Characteristics pertaining to ancient Man in Michigan. Smithson. Rept., Wash., 234–245, 13 figs., 1875.

Indians in Bolivia and probably in the highlands of Peru still perform this operation, and thus express their belief in its efficacy. The operation in Bolivia is performed by the shaman, who is often also a medicine man, with a well sharpened pocket-knife, piece of sharp glass or sharp-edged stone, (Frontispiece) the process being one of cutting or scraping. The operation is often performed following a depressed skull fracture received in one of the frequent brawls of the Indians on feast days. Many of the skulls (see Chapter XV) showed evidences of more than one operation and as many as four were seen. The openings are large and crudely made and the operation, fatal in a very high percentage of cases, must have been excruciatingly painful.

Common and widespread (Figure 29) as trephining was in Neolithic times yet very little is known of its purpose or the method of procedure of the prehistoric surgeon. Broca decided that prehistoric surgical trephining was performed for the relief of certain internal maladies. He suggested that it was performed on young epileptic or mad persons to rid them of the "genius," the "demon" causing the dreaded symptoms. They may have performed the operation for the relief of depressed fracture, but as most of the trephined skulls show no signs of accidents, headache was very probably the chief indication for this operation. A religious significance has been attached to the procedure but there is no recent evidence to support this view.

The trephine hole (Plate LXXII, *c*) is usually located on the upper and posterior part of the parietal bone,[18] probably because this region was most easily accessible to the operator in a period when beds and chairs were not used. The operation, according to Lucas-Championniére,[19] was not performed by scraping, since this would take a long time, would result in profuse hemorrhage, and would not result in the production of a rondelle or cranial amulet, so prized by prehistoric peoples for wearing as a necklace (Fig. *b*, Plate LXXII), but was doubtless produced by a sharp cutting or sawing instrument, doubtless similar to the methods employed by the New Caledonians today.

The operation was often performed several times on the same person and Neolithic skulls are known with three and four trephine openings. Its frequency is suggested by the discoveries in the Neoli-

[18] The two skulls described by Manouvrier (1903) were trephined, one in the temporal, the other in the posterior part of the frontal. One of the skulls described by Pruniéres is trephined in the right occipital.

[19] Lucas-Championniére, "La Trépanation préhistorique" Paris, 1878; "Les Origines de la trépanation compressive," Paris, Steinheil, 1912.

thic sepulchral chambers at Vendrest, some sixty miles to the east of Paris. Remains of over a hundred and twenty individuals, representing both sexes and all ages, were found within this ancient tomb. A fall of earth and rocks had buried the doorway of the sepulchre about the close of the Neolithic period, for all the worked flints and ornaments found within the sepulchre were of that age. No less than eight skulls had been opened by trepanning and many of them had survived the operation as seen by the healing of the edges of the wounds, a process of extreme slowness in the injured skulls of adults.

THE USE OF THE CAUTERY AMONG NEOLITHIC AND LATER PRIMITIVE PEOPLES AS A CAUSE OF SKULL LESIONS

The anthropologic features of cauterizations were first investigated by Manouvrier, a French anthropologist, who studied the curious lesion, since known as the sincipital T, on skulls bearing marks of cauterization of the scalp (Figure 31) from dolmens belonging to the Neolithic period (3000-7000 B. C.). The crania in question were collected from the Dolmen de la Justice at Epône, near Mantes, on the Seine River, Seine-et-Oise, in France. This dolmen had been known since 1833, as MacCurdy tells us,[20] and it was commonly supposed from its dilapidated appearance that it had long ago been explored and robbed of its contents. In 1881 M. Perrier de Carne, of Mantes, thought it worth while to obtain from the owner, Madame Piot, a permit to excavate, and was surprised to find the sepulture, which usually lies beneath these mounds, intact and containing pottery, stone implements, ornaments, and portions of 60 skeletons, with 12 crania. These dolmens are often extensive, the largest known covering an area of five and a half acres, and attaining a height of 130 feet. Under the earth mounds are usually found sepulchral chambers; often interesting examples of primitive architecture. The highest expansion of the dolmen is to be found in the pyramids of Egypt, which are elaborate examples of the same idea. The Indian mounds, so common in North America, are of the same type, and instances of similar methods of burial are found in South America in the chulpas of ancient Peru. There are many thousands of these dolmens in western Europe,[21] about 8000 in England alone.

[20] G. G. MacCurdy: 1905—Prehistoric Surgery—a Neolithic Survival. Amer. Anthropol., vii, No. 1, pp. 17–23, 1 plate.

[21] F. Pomerol, 1894. Squelette humaine néolithique avec crâne trépané et lésions tuberculeuses des vertébres. Assoc. franc. pour l'avance d. sc. C. R. 1893, Paris, xxii, pt. 2, 699–706.

The skeletal material, obtained from the Dolmen de la Justice, at Epône, was referred to Professor Manouvrier for study and description. Among other interesting observations he noted that 3 of the female crania were marked by curious lesions on the vertex, and similar on all the skulls. The mutilations were in the form of a T-shaped (Plate LXXIII) cicatrice, for which Manouvrier could offer no explanation. The lesion takes the form of a long anteroposterior groove or ridge, extending from the anterior curve of the frontal, along the sagittal suture, terminating usually near the obelion, where the transverse branch is encountered, but at times extending on down over the occiput to near the foramen magnum. In a Peruvian skull, (Plate CIV) described below, the sagittal lesion has a length of 210 mm. fading out into indefinite lesions anteriorly and posteriorly.

The transverse lesion is not long, having in the Peruvian skull a length of 150 mm., though in the Neolithic skulls it was shorter. The transverse lesion is in all cases curved anteriorly. The scars in the Neolithic skulls are evidently the result of lesions of the scalp made during life, and are often deep enough to affect either directly through contact or indirectly through suppuration the periosteum and adjacent bone.

Manouvrier found in the Broca collection 3 other female skulls showing similar cicatrices. These skulls came from dolmens in the neighborhood of the Dolmen de la Justice, and were found in the dolmens at Vaureal, Conflans-Sainte-Honorine, and Feigneux, all in the Department of Seine-et-Oise. The lesion in one of these 3 skulls was very slight, in the other either the wound or the subsequent suppuration had uncovered the diploë.

No other pathologic features were present on the skulls. The lesions were often interrupted, as if the knife making the incision did not always come in contact with the periosteum. Various explanations were offered for these lesions, and Manouvrier suggested that an explanation might be found in practices connected with religion, war, penal justice, mourning, therapeutics, and coiffure. The lines of incisions usually follow the line of parting of the hair, and it is possible that the incisions were made here because of the ease of access.

Interest in the subject was thus aroused, and other dolmens north of Paris were searched for further examples of skulls bearing the sincipital T. Among 40 skeletons found by M. Fouju in a dolmen of Menouville, near l'Isle d'Adam, north of Paris, 5 skulls showed evidences of surgical interference; 3 undoubted cases of trepanation; the

other 2 showing portions of the sincipital T. After studying other specimens, especially those described by Verneau from the Dolmen de-Mureaux, Manouvrier reached the conclusion (Plate LXXIII) that cauterization by burning or other treatment appeared the most probable, and doubtless corroborated the idea that there were surgeons among many of the Neolithic peoples who lived near the Seine and the Oise rivers who had recourse to the process as a therapeutic measure not less terrible than their practice of trepanation.

The next step in the proper interpretation of these ancient lesions was a comparison between the prehistoric evidences and more recent ones, especially the ancient Guanche skulls described by von Luschan from the Canary Islands, where 25 skulls showed scarification similar to the Neolithic ones studied by Manouvrier. Von Luschan regarded the operation as related to trepanning and distinctly of a surgical nature.

An intimate insight into the possible method of procedure among the Neolithic surgeons in cauterization may be gathered from the quotation, given by MacCurdy, from the work of Lehmann-Nitsche, who says that the ancient chroniclers of the Canary Islands, as cited by Chilly Naranjo, say that:

> They made large scarifications with their stone knives on the skin of the part affected, and then cauterized the wound with roots of malacca cane dipped in boiling grease; preference being given to the use of goat's grease.

This suggestion of Lehmann-Nitsche's, combined with a new observation by Manouvrier on ancient surgical practices as outlined by Brachet, prove beyond question that the sincipital T marks on ancient crania and those of later times may be explained on the same basis—that of cauterization. Brachet quotes Avicenna and Albucasis, as set forth in the works of Daremberg and Leclerc, to the effect that in cases of melancholia cauterization was resorted to in order to reduce the amount of cold humors in the head. Sudhoff has shown the various types of incisions made for cauterization of the forehead, temple, and sinciput. These are shown in Figure 31, A, B, C. That this surgical lore was handed down from Neolithic times to the surgeons of the Dark Ages there can be little question. Some of the links in the chain of evidence are lost owing to the practice of incineration in some periods, but enough is known to establish the practice beyond question. The final link was supplied by Manouvrier, who described a skull (Plate LXXIII) which showed in numerous ways the results of the cauterization in a female skull from the dolmen of Champignolles, between the Seine

and the Oise. As may be seen from the figure, the skull is perforated in two places. These openings are, without doubt, the result of cauterization (Frontispiece) and may have been intentionally burned there by the surgeon in his zealous desire to drive out the demon of melancholia.

It is a long way from the Seine-et-Oise country (Figure 29) to Peru, but in this latter place evidently the same practice (Plates CIV and CV) came into existence some five thousand or six thousand years later. It is not surprising to find this same practice in these widely separated areas, since it has been previously shown that trephining was practised in northern France (Plate LXXII) and in Peru (Plates CVII-CIX) and very little elsewhere in ancient times. These two regions seem to have been the foci for the development of primitive surgical practices, though there was no means of intercommunication possible.

It is extremely odd that nearly all the injured skulls, with possibly two exceptions, were female. The Peruvian skull is that of a female (Chapter XV). The lesions on the pre-Columbian female skull from Peru may be regarded as a variant of the Neolithic T (Moodie, 1921.1). The surgeon[22] seems to have been eager to make a good incision, since he penetrated not only the scalp and the galea aponeurotica, but also the periosteum and left a widely gaping wound, which after contact with the cauterizing substance, boiling oil or heated object, became violently infected, and produced during the course of a few weeks an enormous hypertrophy of bone, especially in the outer skull table. The incisions, instead of making a sincipital T, are in the form (Figure 31) of a latin cross with the longer portion of the upright anterior to the obelion (see Frontispiece).

THE AMPUTATION OF FINGERS AMONG PRIMITIVE RACES

The primitive mind worked in a curious manner. If an ancient man performed a procedure which we today called surgery he was not aware of doing anything unusual or unique. When the shaman, medicine man, or priest amputated a finger, trephined a head, cauterized a scalp, or sucked the pus from a wound, he had no intention of counteracting some antagonistic phase of nature, but to exorcise a demon, to let out the evil spirits, or to in some manner appease an angry god. Gods dwelt in every object of nature and the simple mind of man saw only the steps necessary to appease them. Surgery thus had its begin-

[22] A. F. LeDouble, 1889. La Médicine et la Chirurgie dans les temps préhistoriques. Tour, 8°.

nings, and to these simple beginnings we have applied the name of surgery, because we have adapted them to other ends. Science of all kinds was nebulous in its origin.

Shamanism, from which early surgical procedures were evolved, is well known in many parts of the world as a phase in religious evolution. All races of men at an early stage of their development display this form of concept in some manner. Although the term was first applied only to the practices observed among some tribes of northern Asia, it has lately been more generally used to express the placation and control by magic and fetichistic rites of spirits or demons who are supposed by primitive man to rule all mankind and, indeed, the whole realm of nature. The shaman was thus not only a practitioner of sorcery, able to drive off the spirits which bring death, sickness and misfortune, and to invoke others which confer success and love, but he was a priest, who by communion with the higher powers learns and afterward teaches to others the form of practice used in the cult. The term "medicine-man" is an awkward compound, invented by the early explorers of North America, which is entirely misleading, since it conveys some conception of therapeutics. If they had a pharmacal knowledge or any idea of healing it was a secondary matter to that of appeasing the spirit.

The practices evolved by a race in its more primitive state were abandoned after they had progressed to a better understanding. Thus trephining was not used as a relief for headaches or to let out the demon after the rise of the conception that the god could be as well appeased by some allegoric object, such as a gourd with an opening, which was presented as a trephined head to the god, who would accept it in lieu of the actual operation. Surgery among the primitive races of man is thus a very obscure thing. That primitive men had any definite conception of what constituted surgery is doubtful. The processes performed by them we call surgery now, and they do indicate some knowledge of ligation, stoppages of hemorrhage, sepsis, and the like. They had, too, some meager knowledge of anatomy.

When an Australian native slashed his arms or body crosswise with a flint knife to make the beautifying scars (Figure 35) necessary to his idea of cosmetics he was always careful to avoid cutting any of the larger arteries. It is, therefore, the intention to point out the procedures among ancient man which indicate any knowledge of anatomy, surgery, or treatment, on the basis of which a logical evolution of modern surgery may be founded.

How or why primitive man came to the conclusion that the amputation of a finger or fingers would appease a god or add to their personal beauty is unknown. We do know, however, that the later Paleolithic races (the Aurignacian) of France and Spain, who inhabited that country some seven thousand years ago, had practised the sacrifice, since they have left silhouettes of hands with amputated finger stumps (Figure 33) on the walls of many caves. These silhouettes were made, doubtless, by placing the hand on the wall of the cave and blowing thereon a mouthful of pigment, red ochre, or other mineral pigment which they used to adorn their persons. The impulse to do this is doubtless the same which induces the average school child to outline his hand in pencil or chalk. At any rate, these silhouettes, protected from the weather in the caves, show us that it is an old custom and we know it persists to the present day.

Such imprints have been found on the walls of caves in California, Arizona, Peru, Africa, and Australia in recent times, (Figure 34) and a similar imprint, known as the "red hand," has also been observed in Egypt, Palestine, Arabia, Babylonia, India, Phoenicia, and Mexico. The custom is thus well authenticated. The purpose of the amputation was as various as the countries in which it was employed. It was a symbol of mourning in the Nicobar Islands. It was a sacrifice in India, demanded at the death of a ruler. It was a part of the initiation ceremony among certain Indians of North America; to appease a god; as a distinguishing mark of caste; as a preparation for marriage, and for other obscure reasons.

The operation was often confined to the little finger, and was performed by a flint knife, the incision being made at the joint and the first amputation involving only the terminal phalange. Hemorrhage was stopped by a bandage, by applying fats, and by heat, such as a heated stone. Rare cases have been observed in which an individual, usually a woman, had sacrificed the last two joints of all fingers of both hands. Imprints on the Aurignacian caves of the Paleolithic of France indicate a similar extent of the practice. The surgical aspect of the amputation is obscured in its symbolism, but that it was a surgical procedure is obvious. Ligation was often employed in severing a finger-joint. A thread of sinew being bound about the joint was daily constricted until the joint fell off. An Indian youth was observed to place his finger on the sacred buffalo skull and chop it off with a stone hatchet. Such a sacrificial custom indicates some slight surgical knowledge, though of a crude variety.

The primitive races of Australia and some of the races of Africa at the time of puberty, or later, have a custom of scarifying the body with long, though not deep cuts of a flint knife, involving the skin (Figure 35) and superficial fascia. The resulting scar tissue was thought to be very beautiful. Scarification of the tissues for therapeutic purposes has not been seen. Some knowledge of anatomy was expressed by the care that was taken to avoid the larger blood-vessels, and a few cases of death from hemorrhage have been recorded. The incisions, made a few at a time, bled profusely, and no apparent attempt was made to control the flow of blood. The individual was often greatly weakened. To secure a beautiful adornment of the entire body often consumed several weeks or months. It is remarkable that there are so few cases of sepsis involved either in tattooing or scarification, and the absence of keloids, to which negroes are especially prone, is an interesting commentary to the oft-recorded observation of the immense resistance possessed by primitive races of man and wild animals. We are thus more readily able to understand the rarity of pathology among ancient and primitive races of uncivilized man. We pay for our civilization in terms of pathology and lowered resistance.

DESCRIPTIONS OF FIGURES 28-35 AND PLATES LXIX-LXXIII ILLUSTRATING CHAPTERS XI AND XII

FIGURE 28

Geographic distribution of the phases of trypanosomiases affecting animals. (After A. Laveran and F. Mesnil, 1912. Trypanosomes et Trypanosomiases, p. 5.)

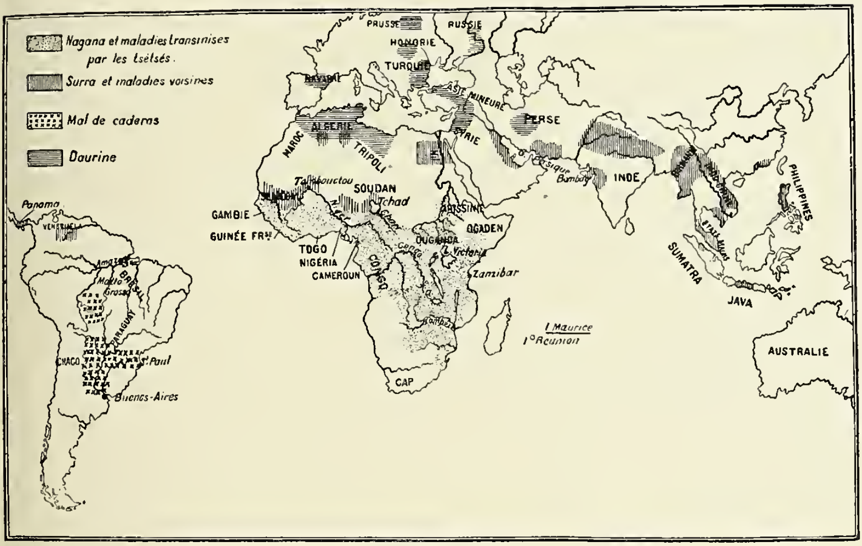

Nagana et maladies transmises par les tsétsés.
Surra et maladies voisines
Mal de caderas
Dourine
PRUSSE
RUSSIE
HONGRIE
TURQUIE
ASIE MINEURE
PERSE
ALGÉRIE
MAROC
TRIPOLI
SYRIE
SOUDAN
Tchad
GAMBIE
GUINÉE FRse
TOGO
NIGÉRIA
CAMEROUN
CONGO
OUGANDA
OGADEN
Victoria
Zamibar
CAP
I. Maurice
I. Réunion
INDE
Bombay
SUMATRA
JAVA
PHILIPPINES
AUSTRALIE
Panama
Amazone
BRÉSIL
Matto Grosso
PARAGUAY
CHACO
St Paul
Buenos-Aires

FIGURE 28

FIGURE 29

FIGURE 29

Outline map of the world showing distribution of the areas in which prehistoric trephining is known to have occurred.

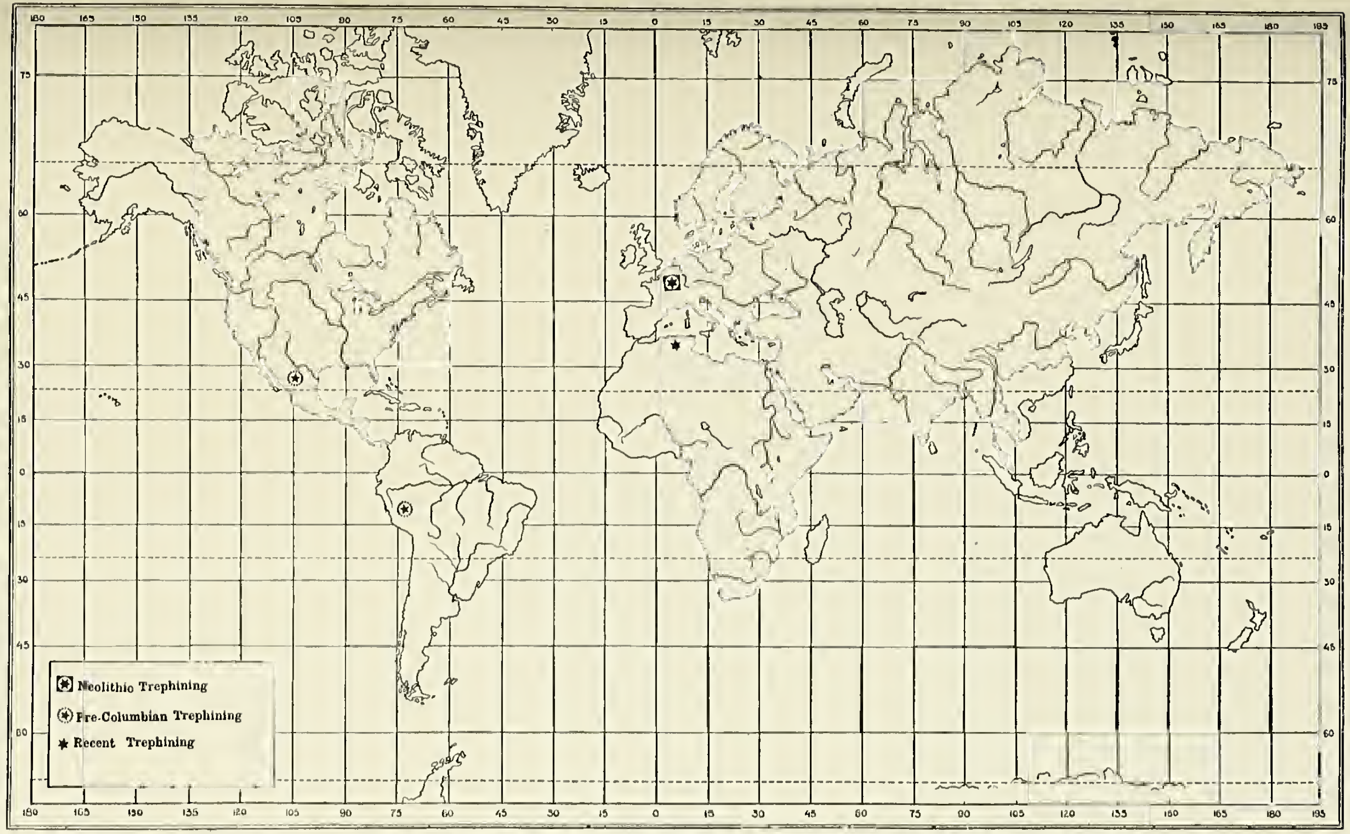
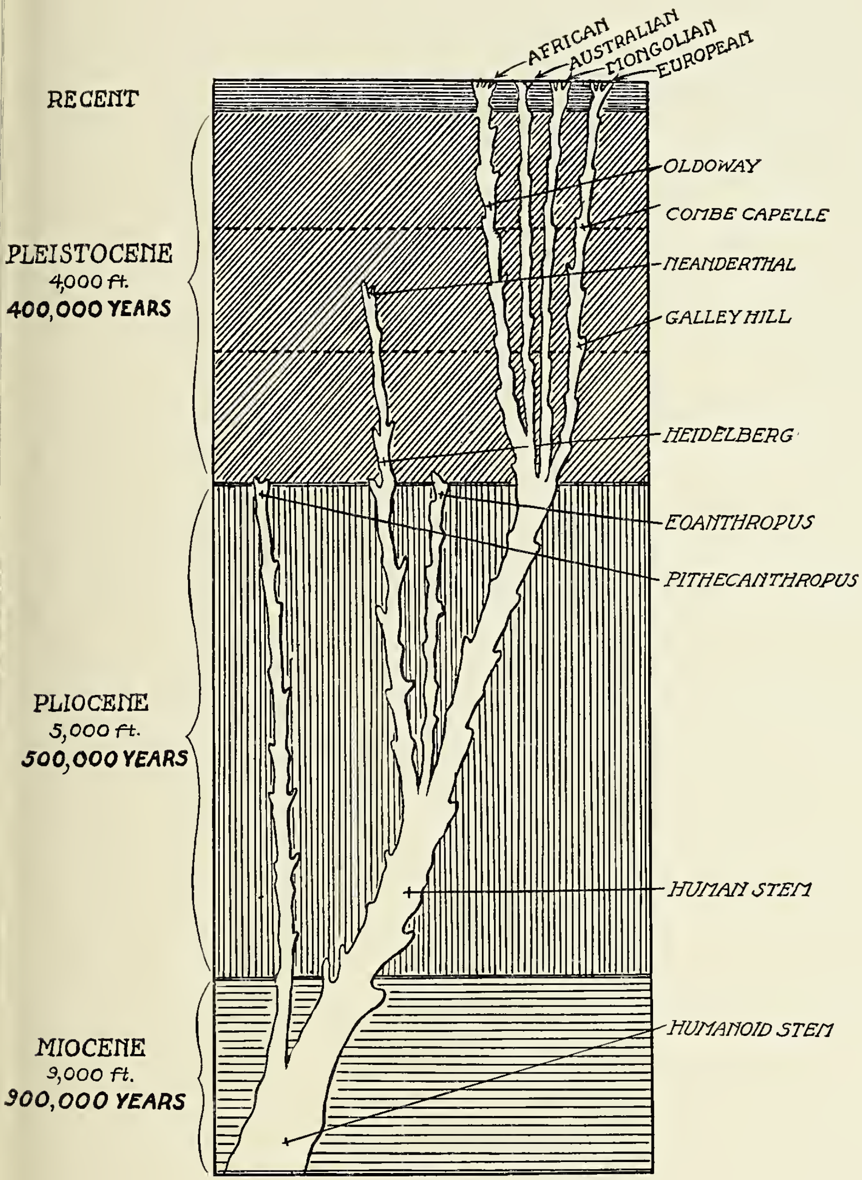

Neolithic Trephining
Pre-Columbian Trephining
Recent Trephining

FIGURE 29

FIGURE 30

FIGURE 30

The relations of the early human types as seen in a genealogical tree of man's ancestry. The depths of the rock deposits and the duration of the geological periods are based on estimates by Sollas. An inspection of the figure shows how little is known of the ancestry of man, but it represents, in concrete form, a working hypothesis. On it one may trace the development of surgical knowledge. (After Keith.)



AFRICAN
AUSTRALIAN
MONGOLIAN
EUROPEAN
RECENT
PLEISTOCENE
4,000 ft.
400,000 YEARS
PLIOCENE
5,000 ft.
500,000 YEARS
MIOCENE
9,000 ft.
900,000 YEARS
OLDOWAY
COMBE CAPELLE
NEANDERTHAL
GALLEY HILL
HEIDELBERG
EOANTHROPUS
PITHECANTHROPUS
HUMAN STEM
HUMANOID STEM

FIGURE 30

FIGURES 31-32

Figure 31

Schemata of scalp incisions made at various periods, from the Neolithic to the Middle Ages, to allow the application of heated objects, irritants, or other substances to the heads of demented individuals, usually women. A, B, and C show the type of incisions made in the Middle Ages for the relief of the "cold humours in the head." (After Sudhoff.) A made on the forehead. B made on the temple. C made on the occiput. D the type of incision used by the Neolithic surgeons of northern France, of which A, B, and C, are doubtless descendants, though they differ from the variant of the sincipital T used in Peru, and seen on the female Peruvian skull shown in Fig. 49.

Figure 32

Map showing location and relation of Neolithic and recent trephining in Europe and northern Africa.

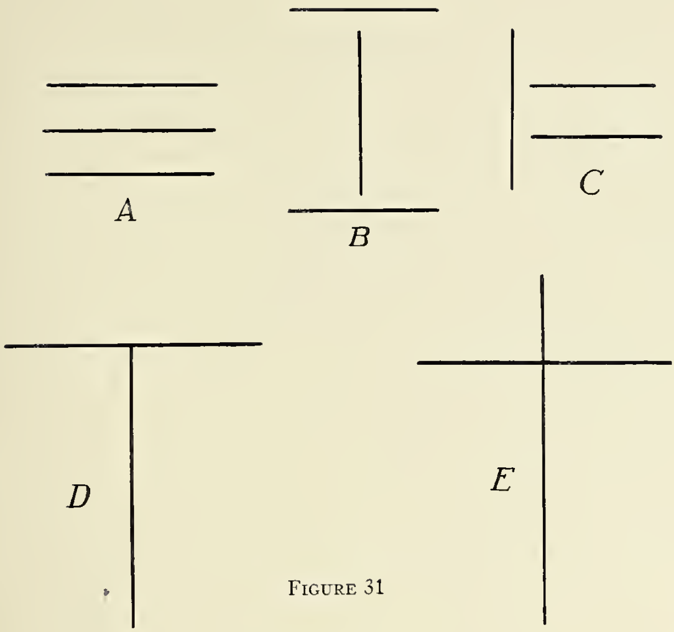


FIGURE 31

FIGURE 32

FIGURES 33-34

FIGURE 33

Silhouettes of hands in red and black, as depicted on the walls of the cave at Gargas, Spain, of the Aurignacian age (late Paleolithic, possibly 20,000 years old). These impressions of amputated hands and fingers were selected out of a series of over 200 and indicate a truly shocking prevalence of finger amputations among these primitive peoples. Numerous attempts have been made to show that these imprints do not represent amputations, but without success. The custom has doubtless been prevalent since early in the Paleolithic and has endured today. It is the representation of the oldest surgical procedure; older even than trephining. (After Sollas.)

FIGURE 34

Virchow's figures of mutilated hands of a Bushman seen from the back. A. Last joint of little finger amputated, but retains a vestige of a nail. B. Similar to A. but with no trace of a nail. C. The last joint of the first and second finger and the tip of the third have been removed. A. and B. male; C. female.

FIGURE 33

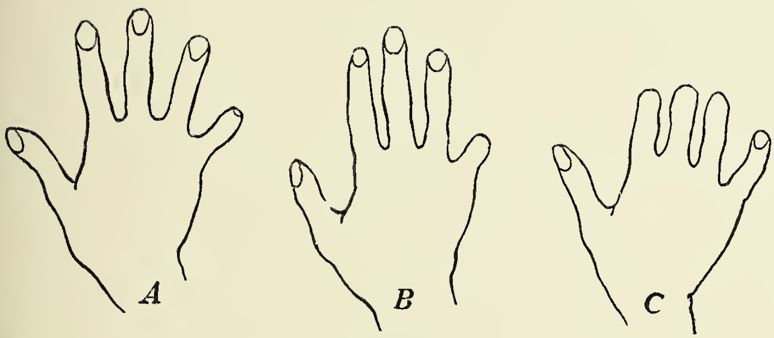


FIGURE 34

FIGURE 35

FIGURE 35

a. Scars on the body of an Australian native.

b. Primitive knife which may have been used in making the cuts. (After Sollas.)

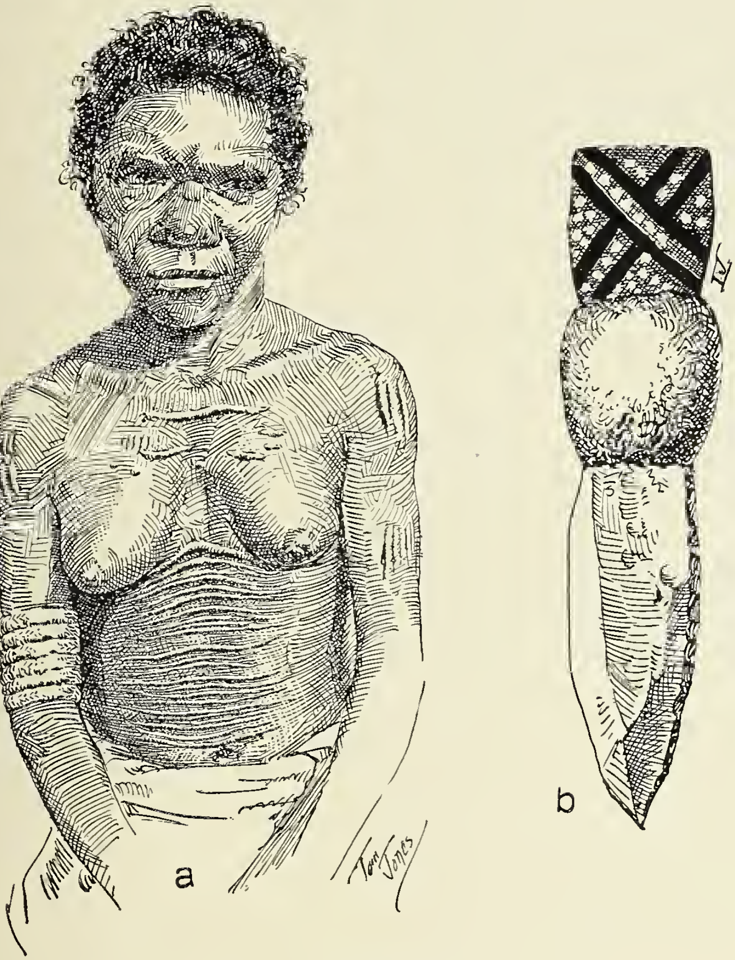


Figure 35

PLATE LXIX

PLATE LXIX

NEOLITHIC POTT'S DISEASE

a and d. Right and left views of the upper dorsal vertebrae of a young man of the Neolithic period (5000 B. C.) found near Heidelberg and regarded by Bartels as indicative of the oldest case of Pott's disease. The symbols "R2," etc. refer to the costal articular facets. The Roman numerals indicate the position of the vertebrae in the thoracic series. The kyphosis is quite evident. (After Bartels.)

b. A fossil tsetse fly, *Glossina veterna* Cockerell, from the Florissant, Oligocene, shales of Colorado. The specimen is 12.5 mm long. Photograph by courtesy of Dr. R. S. Bassler.

c. Radiograph of the necrotic area of above series. (After Bartels.)

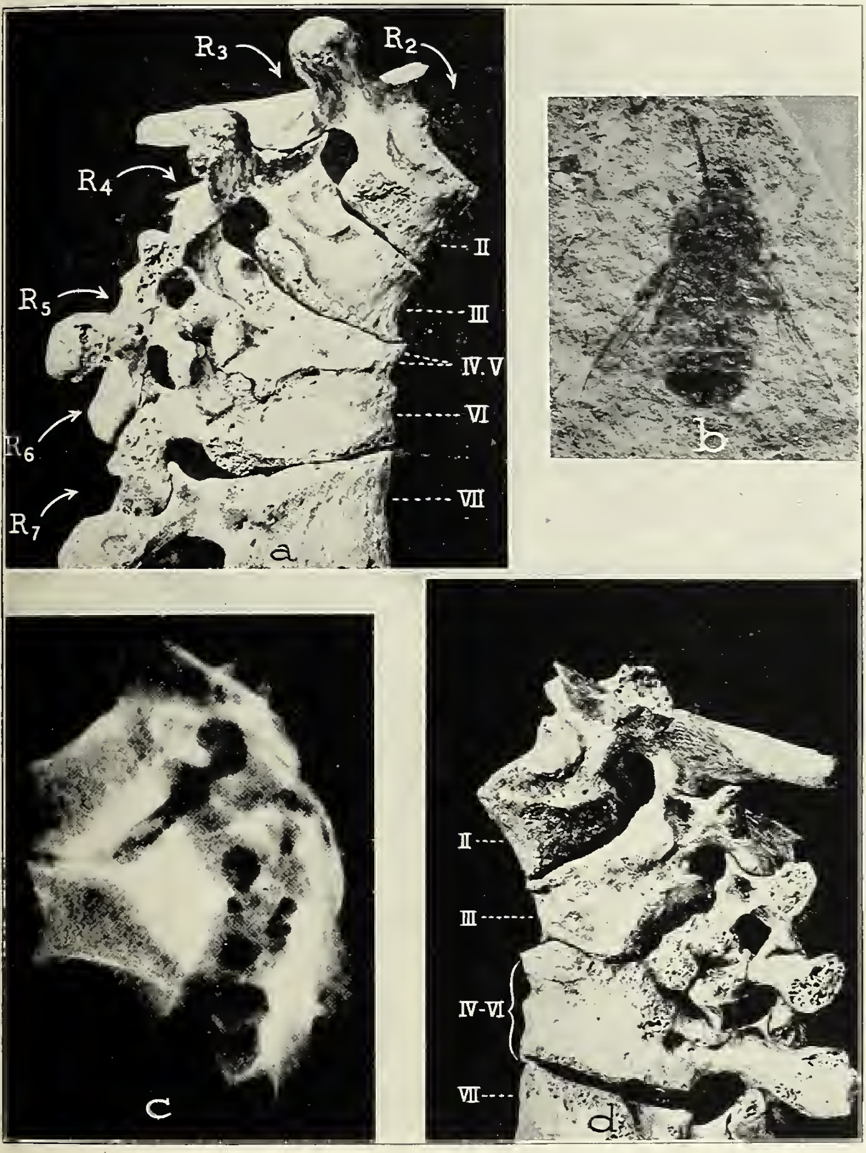


PLATE LXIX

PLATE LXX

PLATE LXX

STONE AGE INJURIES

a. Human lumbar vertebra of a late stone age man (Neolithic) pierced by a flint arrowhead, found in a cavern sepulcher near the Marne, France. (After Verneau.)

b. Lumbar vertebra of a late stone age man (Neolithic) with a flint arrowhead embedded in the visceral surface. The stone age hunter was shot, either purposely by an enemy or accidentally by a companion. The arrow-point entered the abdomen near the umbilicus and the man died shortly afterwards, possibly from a hemorrhage due to the severance of a large artery. So firmly fixed was the arrow-point that it has remained embedded in the bone for more than 7000 years when it was found by a noted young archeologist, Déchellette, who himself lost his life in the great war soon after sending the photograph to Dr. Breasted, from whose reproduction the drawing was made.

c. Lumbar vertebra of a young reindeer, Neolithic period, pierced by a flint arrowhead. It will be noted that the arrow-point injuries shown in a, b, and c are all in *lumbar* vertebrae, possibly because in this region of the body the vertebral column is more exposed to trauma, the thoracic and cervical being better protected by limbs and ribs. (After Verneau.)

d. Human tibia with an ornamented flint arrowhead embedded under a considerable amount of callus, shown by the exostosis to the right. (After Cartailhac, from a specimen found at Font-Rial, France.)

e. The injured rib and the circumstances under which it was found form an interesting instance of how ancient events may be reconstructed. The wound was inflicted on the rib of this wild bull by the arrow of a late stone age hunter, and a later wound brought about the death of the animal in the Danish forests possibly 10,000 years ago. At the fatal hunt several arrows pierced the bull's vitals, one of them, however, broke off and the arrow-point found with the skeleton is still preserved in the Copenhagen museum where the animal's remains are mounted. While the wounded bull was trying to swim across a neighboring lake he died and his body sank to the bottom. The pursuing hunter, on reaching the lake, found no trace of his quarry. In the course of thousands of years the lake filled up entombing the body of the bull, and there in the peat his skeleton was found in 1905, and embedded with it were the flint arrows which killed him. (Breasted.)

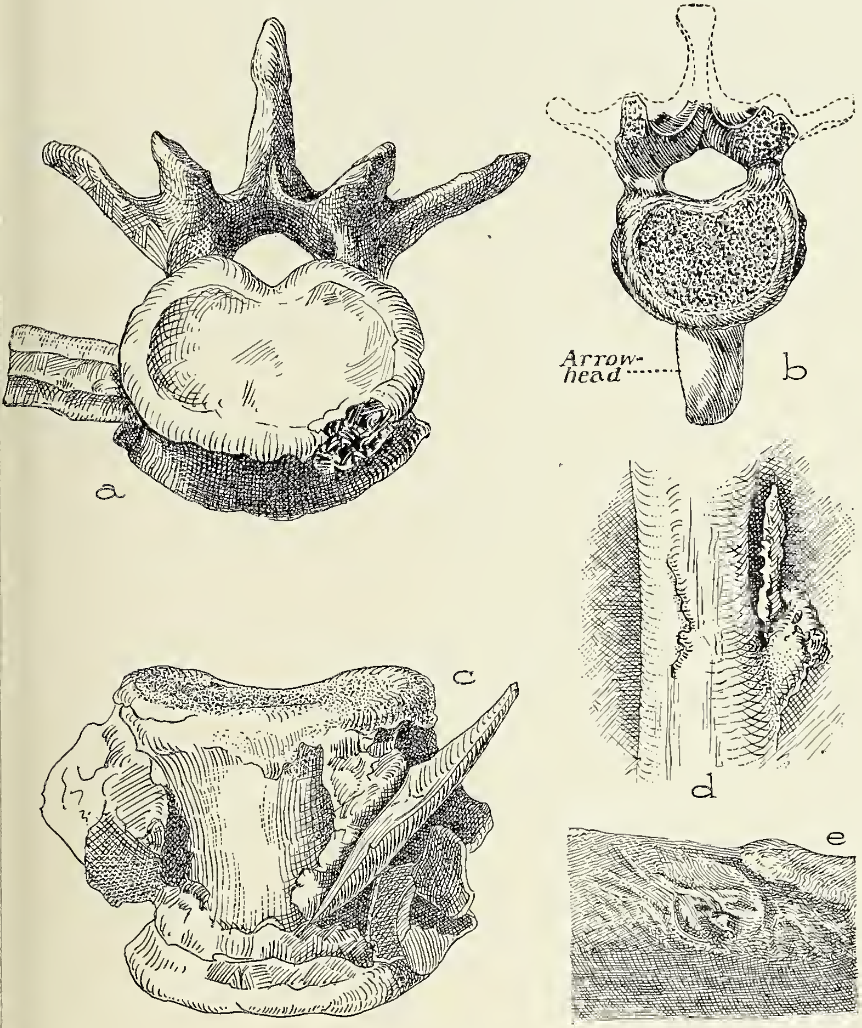


PLATE LXX

PLATE LXXI

PLATE LXXI

ANCIENT HUMAN PATHOLOGY

a. Anterior view of the left femur of the oldest known human representative, *Pithecanthropus erectus*, portions of whose skeleton, 500,000 years old, were found in 1891 in a river deposit in Java. The femur shows an extensive medial exostosis due to some chronic infection or other irritation along the line of the tendinous attachment of the iliopsoas and pectineus muscles. This is the oldest example of human pathology.

b. Posterior view. (After Dubois.)

c. Left ulna of the Neanderthal man showing in the widened olecranal fossa evidences of injury. Drawn from a photograph of the original by Hrdlička.

d. Modern human femur showing medial exostoses similar to those exhibited by the *Pithecanthropus*. This drawing was used by Virchow to demonstrate to the anthropological society of Berlin that the pathology of the most ancient man-like form was similar to modern pathology. Some scholars had argued that the femur was not human, being misled by the pathological deformation.

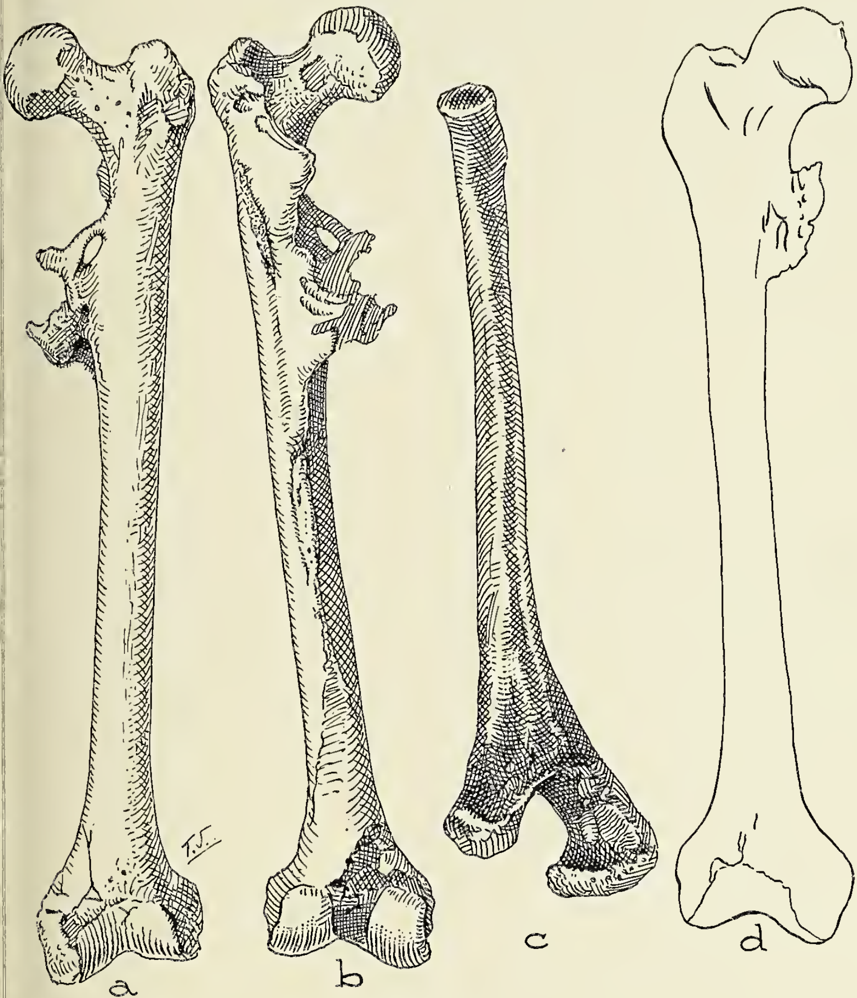


PLATE LXXI

PLATE LXXII

PLATE LXXII

NEOLITHIC TREPHINING

a and b. Cranial amulets or "rondelles" possibly taken from trephine openings in the living, but more probably derived from dead skulls. These are supposed to have been used as charms, and are often perforated (B) and worn as a necklace. (After Fletcher.)

c. Neolithic trephined skull, with the openings in an unusual place. From a cavern on the Marne, France. (After Verneau.)

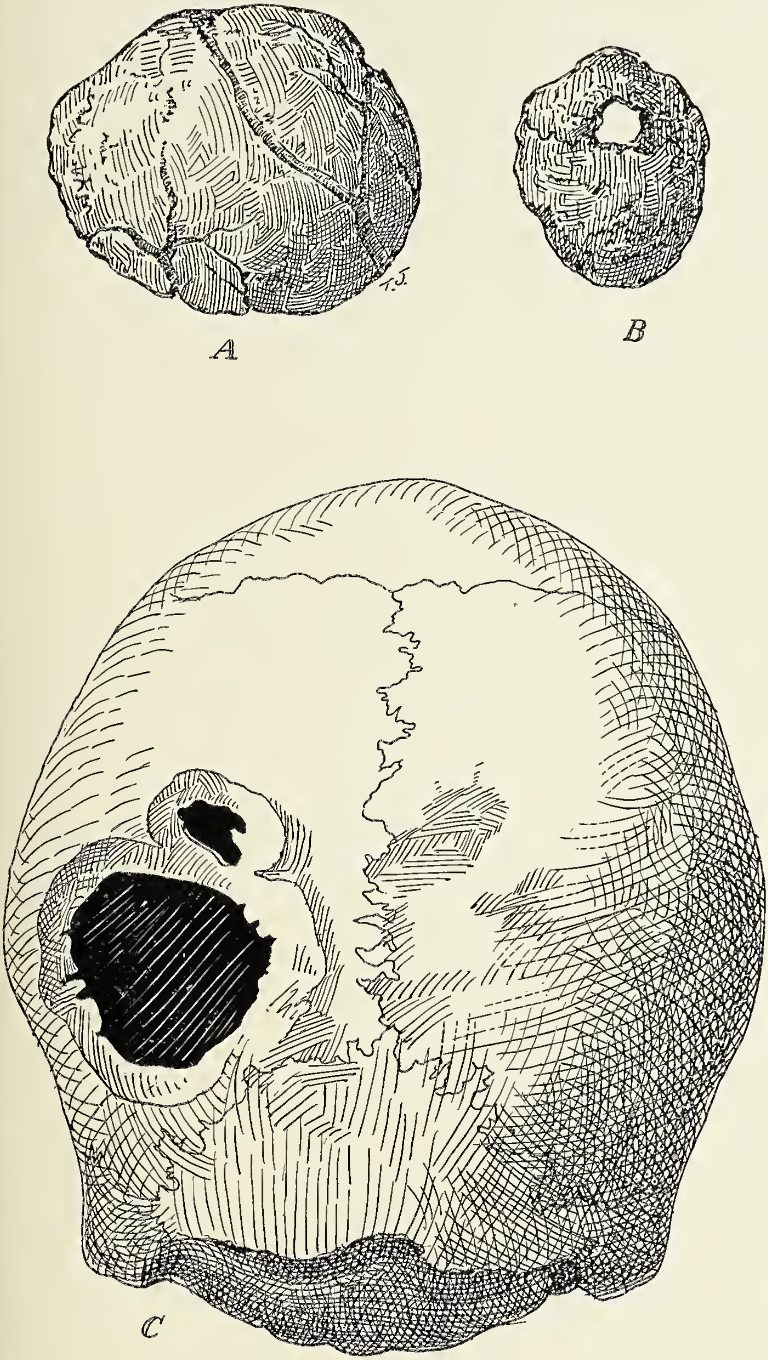


Plate LXXII

PLATE LXXIII

PLATE LXXIII

PRIMITIVE SURGERY

Upper figure. A female Neolithic skull (six thousand years old) from Seine-et-Oise, France, showing the effects of cauterization of the head, possibly for the relief of mental disturbances. The surgeon was so eager to effect a cure that he burned holes through the skull twice on the posterior portion of the right parietal. The sincipital T is shown in the upper left corner. The slight scar on the right frontal is an accidental burn. (After Manouvrier.)

Lower figure. An example of modern primitive surgery. A trephined skull, showing also effects of the cautery, of an inhabitant of Kabylia in northern Africa. The results are incomplete indicating possibly that the patient died during the operation. (After Verneau.)

Plate LXXIII

CHAPTER XIII

DISEASES OF THE ANCIENT EGYPTIANS

Biographical sketch of Sir Marc Armand Ruffer. Diseases of the ancient Egyptians. Chronological table of kings of Egypt. Arteriosclerosis in the aorta of the Pharaoh of the Exodus. Other arterial lesions among early Egyptians. Histological studies of Egyptian mummies. An eruption resembling small-pox. Vesical calculus. Early evidences of schistosomiasis. Rickets in ancient Egypt. Appendicitis. Symmetric osteoporosis of the skull. Prolapsus viscerum. Hydrocephalus in early Egypt. A psoas abscess-tuberculosis-Pott's disease. A pelvic osteosarcoma. Osseous lesions in early Egyptians. Poliomyelitis. Trephining in Egypt. Lesions in the mummified animals of Egypt. Syphilis in Egypt. Descriptions of Figures 36–41 and Plates LXXIV–LXXXVII illustrating Chapter XIII. Figures 36–41 and Plates LXXIV–LXXXVII.

BIOGRAPHICAL SKETCH OF SIR MARC ARMAND RUFFER[1]

Sir Marc Armand Ruffer was born at Lyons, France, in 1859, the son of Baron Alphonse Jacques de Ruffer. He was educated at Brasenose College, Oxford, where he took, his B. A. degree in 1883, and at University College, London, becoming a bachelor of medicine and surgery in 1887 and M. D. in 1889. He then became a pupil of Pasteur and Metchnikoff at the Pasteur Institute, devoting special study to the then novel subject of phagocytosis. He described the diphtheritic membrane as "a battlefield," in which pathogenic bacteria and amoeboid leucocytes contend for mastery. In 1891, Ruffer became the first director of the British Institute of Preventive Medicine. At Metchnikoff's suggestion, Ruffer took up the study of cancer and established the provisional status of the quasi-parasitic formations in cancer cells. While testing the new diphtheritic serum at the Institute, Ruffer was so severely smitten with the paralytic sequelae that he felt compelled to resign his directorship. He then went to Egypt for recuperation and subsequently took up his permanent residence at the Villa Ménival, Ramleh, Egypt.

He later became professor of bacteriology in the Cairo Medical School, and was president of the Sanitary, Maritime and Quarantine Council of Egypt (1901-17), in which office he was instrumental in

[1] Extracted from "Memorial Notice of Sir Marc Armand Ruffer" by F. H. Garrison. Ann. Med. Hist., N. Y., i, no. 2, 218–220, portrait.

ridding Egypt of cholera by rigorous hygienic policing of the routes of pilgrimage at the Tor Station and elsewhere.

He made his mark in the medical history of ancient Egypt by his contributions to its paleopathology, in particular the paleohistology of the pathological lesions found in mummies of the XVIII-XXVII dynasties.

At the opening of the European War he was head of the Red Cross in Egypt. He left, in the winter of 1916-17, for Salonika, to reorganize the sanitary service of the Greek Provisional Government, and met his death at the hands of the enemy while at sea in the spring of 1917. Thus were interrupted his studies on the paleopathology of Egypt, but Lady Ruffer has already prepared a volume of antiquarian studies (Ruffer, 1921) which will be a permanent record of his unique and memorable discoveries in the paleopathology of Egypt.

DISEASES OF THE ANCIENT EGYPTIANS

It was in Egypt that the foundations for the study of Paleopathology were first laid. Fouquet[2] initiated the subject in Egypt, so successfully followed by Sir Marc Ruffer. The pathological conditions which are encountered among these ancient Egyptians, covering a range of several thousand years, are many. Pott's disease (Plate LXXIV), pneumonia, small pox, (Plate LXXVII), deforming arthritides of many kinds, renal abscesses, arteriosclerosis (atheroma), many types of fractures, necroses, tumors (Plate LXXIX), cirrhosis of the liver, caries, alveolar osteitis (Plates LXXXIV-LXXXV), and many other interesting lesions may be discerned.

Syphilis has been reported by De Morgan (1897) to occur among the ancient Egyptians, although the evidences, as indicated by Fouquet, are uncertain. Lortet and Gaillard, (1903-1909), in their study of the ancient fauna of Egypt, such as birds, lizards, crocodiles, antelope, bulls, dogs, cats, and other forms of vertebrates, have reported lesions of syphilis on the skull (Plate LXXXVI) of a young woman. The lesions take the form of irregular erosions in the outer table of the frontals and in the anterior portion of the parietals. They recall those described by Eaton (1916), in a child's skull from ancient Peru, ascribed to syphilis (Plate CII, b).

[2] Fouquet's results are to be found in the 1897 volume of J. De Morgan's "Recherches sur les origines de l'Egypt" under the heading "Observations Pathologiques" pp. 350–373; also the 1896 volume p. 225 and 268.

The first attempt to review the field of Egyptian Paleopathology ʼas made by Dr. Klebs, who discussed osteitis deformans, tuberculosis, steoporosis (Plate LXXX), rachitis and syphilis, injuries, fractures and islocations (sepsis) and diseases of the soft tissues. He closes his rticle, based on a paper read before a meeting of the Johns Hopkins Iospital Historical Club, with the best bibliography of papers which as so far appeared. Similar reviews are given by Garrison and udhoff.

The following accounts of diseases in ancient Egypt are based on he literature. I have had many of the illustrations redrawn and have bstracted all available articles. In order to make the discussion of he relative age of the various mummies more understandable there s appended a "Chronological Table of Kings of Egypt." The value of he study of mummies has been as important from an historical as rom a medical standpoint.

Accounts of the diseases of modern Egyptians are given by Sand-vith[3] and by Hrklička,[4] but since modern diseases do not immediately oncern us the reader is referred to these authors.

CHRONOLOGICAL TABLE OF KINGS OF EGYPT

(After Breasted—1909—History of Egypt, p. 597–601)

See ancient Records of Egypt, I, 38–75)

Jote: All dates with asterisk are astronomically fixed.

ntroduction of Calendar....4241 B. C.

ccession of Menes and Beginning of Dynasties....3400 B. C.

First and Second Dynasties 3400–2980 B. C.

Eighteen Kings....420 years

Third Dynasty, 2980–2900 B. C.

Zoser to Snefru....80 years

Fourth Dynasty, 2900–2750 B. C.

Khufu....23 years

Dedefre.... 8 years

Fifth Dynasty, 2750–2625 B. C.

Userkaf.... 7 years

Sahure....12 years

Neferirkere....X

Shepseskere....7

Khaneferre....x

Nusere....30

Menhuhor....8

Dedkere-Isesi....28

Unis....30

Total—122 years. Minimum 125 years.

[3] Sandwith, F. M., The Medical Diseases of Egypt, London, 1905.

[4] Hrdlička, Aleš, The Natives of Kharga Oasis, Egypt. Smithson. Misc. Collect. Wash. 912, lix, no. 1.

Sixth Dynasty, 2625–2475 B.C.

Teti II
Userkere
Pepi I....................21 years
Mernere I.................. 4 years
Pepi II....................90 years
Mernere II................. 1 year
Total—116 years. Known length 150 years

Seventh and Eighth Dynasties, 2475–2445 B. C.

Known total 30 years

Ninth and Tenth Dynasties, 2445–2160 B. C.

Eighteen Heracleopolitans, estimated..............285 years

Eleventh Dynasty, 2160–2000 B. C.

Horus Wahenekh-Intef I..........50 years
Horus Nakhtneb-Tepnefer II
Horus Senekhibtowe-Mentuhotep I
Nibhapetre-Mentuhotep II
Nibtowere-Mentuhotep III.......... 2 years
Nithepetre-Mentuhotep IV..........46 years
Senekhbere-Mentuhotep V.......... 8 years

Twelfth Dynasty, 2000–1788 B. C.

Amenemhet I..........30 years
Sesostris I..........45 years
Amenemhet II..........35 years
Sesostris II..........19 years
Sesostris III..........38 years
Amenemhet III..........48 years
Amenemhet IV.......... 9 years
Sebeknefrure.......... 4 years

Thirteenth to Seventeenth Dynasties, 1788*–1580 B. C.

Including the Hyksos..........208 years

Eighteenth Dynasty, 1580–1350 B. C.

Ahmose I..........22 years
Amenhotep I..........10 years
Thutmose I..........30 years
Thutmose III..........54 years
Amenhotep II..........26 years
Thutmose IV.......... 8 years
Amenhotep III..........36 years
Amenhotep IV..........17 years
Sakere
Tutenkhamon
Eye.......... 3 years
Total..........227 years

Nineteenth Dynasty, 1350–1205, B. C.

Harmhab..........34 years
Rameses I.......... 2 years
Seti I..........21 years

Rameses II	67 years
Merneptah	10 years
Amenmeses	
Siptah	6 years
Seti II	2 years
Total	142 years

Interim-Anarchy and reign of Syrian usurper 5 years, 1205–1200 B. C.

Twentieth Dynasty, 1200–1090 B. C.

Setnakht	1 year
Rameses III	31 years
Rameses IV	6 years
Rameses V	4 years
Rameses VI	
Rameses VII	
Rameses VIII	15 years
Rameses IX	19 years
Rameses X	1 year
Rameses XI	
Rameses XII	27 years
Total	104 years

Twenty-first Dynasty, 1090–945, B. C.

Nesubenebded	
Hrihor	
Pesibkhenno I	17 years
Paynoseum I	40 years
Amenemopet	49 years
Siamon	16 years
Pesibkhenno II	12 years
Total	134 years

Twenty-second Dynasty, 945–745 B. C.

Sheshonk I	21 years
Osorkon I	36 years
Takelot I	23 years
Osorkon II	30 years
Sheshonk II	
Takelot II	25 years
Sheshonk III	52 years
Pemou	6 years
Sheshonk IV	37 years
Total	230 years

Twenty-third Dynasty, 745–718 B. C.

Pedibast	23 years
Osorkon III	14 years
Takelot III	
Total	37 years

Twenty-fourth Dynasty, 718–712 B. C.

Bekneranef (Bocchoris)	6 years

Twenty-fifth Dynasty, 712–663 B. C.

Shabaka	12 years
Shabataka	12 years
Taharka	26 years
Total	50 years

Twenty-sixth Dynasty, 663–525 B. C.

Psamtik I	54 years
Necho	16 years
Psamtik II	5 years
Apries (Hophra)	19 years
Ahmose II	44 years
Psamtik III	
Total	138 years

Conquest by the Persians (Twenty-seventh Dynasty, 525 B. C.
Alexander the Great seized Egypt 332 B. C.
Egypt under Alexander and his successors, the Ptolemies, 332–30 B. C.
Egypt became a Roman Province 30 B. C.

ARTERIOSCLEROSIS IN THE AORTA OF THE PHARAOH OF THE EXODUS

As evidence of the community of interest between history and medicine may be mentioned the studies of Shattock and Ruffer on the pathological anatomy of the aorta of King Merneptah, the reputed Pharaoh of the Hebrew Exodus. The mummy was found at Thebes, in the tomb of Amenhotep II, who reigned in Egypt from 1449-1420 B. C., and was unwrapped by Dr. G. Elliot Smith, who sent the aorta to the Royal College of Physicians of London. The finding of Merneptah's mummy at Thebes of course discomfited the adherents of the theory that as the Pharaoh of the Hebrew Exodus, he must have been drowned in the Red Sea.

Shattock undertook a microscopic study of this aorta and demonstrated before the Pathological Section of the Royal Society of Medicine in London a section of this aorta.

"The sections showed the picture of typical senile calcification of the aorta, the bony, parallel, elastic lamellae being perfectly preserved, and the interlamellar material thickly strewn with calcium phosphate."

That Merneptah, who reigned in Egypt from 1225-1215 B. C., thirteenth son and successor to Rameses II (1292-1225 B. C.), was a man of great age is shown by his baldness, by the whiteness of the little hair left, by the complete ossification of the thyroid cartilage and of the first rib, not its sheath alone, and by the calcareous patches in the aorta. A single tooth, the upper right median incisor, was visible.

Although the body was reduced to little more than skin and bones, the redundancy of the skin of the abdomen, thighs, and cheeks, indicates that Merneptah was a somewhat corpulent old man.[5]

OTHER ARTERIAL LESIONS AMONG EARLY EGYPTIANS

These interesting observations upon the atheromatous patches in the aorta of the elderly Pharaoh were followed by two studies of Ruffer, (1911), on various arterial lesions found in Egyptian mummies. The earlier and more complete study deals with arteries taken from mummies of the XVIIIth-XXVIIth Dynasties (1580-527 B. C.), and from the time of the Persian conquest (525 B. C.). Ruffer also dissected mummies from later periods so that his studies ranged over material representing a period of nearly two thousand years.

The method of securing the arteries was to dissect them out of broken parts of bodies, such as incomplete arms and legs, where the arteries had been missed in the extensive mutilations of embalming. Dr. Elliot Smith has shown that at the time of the XXIst Dynasty, the embalmers removed the whole of the viscera, the aorta, and most of the muscles of the body and in this process necessarily destroyed the arteries. The artery which most often escaped destruction was the posterior peroneal.

Ruffer's methods of preparing his material for study were very interesting. He first removed the bandages, the mud, sand and gummy material; the limb or trunk was then thoroughly washed and deep incisions were made into the skin. The parts to be examined were then placed in a solution containing carbonate of soda, 1 per cent, and formol 0.5 per cent, and soaked for two days, when the skin usually could be removed. The arteries were completely flattened out. If they had undergone marked fibroid or calcareous changes, the lumen often was patent and the vessel easily seen. The vessels were removed from the surrounding tissues and placed in glycerine to which a few drops of formol were added. For microscopic examination small pieces of a calcified artery were placed in alcohol containing nitric acid, and after 24 hours the piece washed in water, hardened, embedded in paraffin and cut in the usual manner.

The description of an aorta and several arteries may be considered typical of all the arteries he studied. An aorta from a mummy of the XVIIIth-XXth Dynasties showed that the arch had been hacked

[5] The unwrapping of Pharaoh's mummy is fully described by Professor G. Elliot Smith: "Annales du Service des Antiquités de l'Egypt," 1907.

away by the embalmers, who had also cut right through all the coats just above the bifurcation of the vessel. The thoracic aorta from a point above the origin of the left subclavian artery and the whole of the abdominal aorta were intact and easily removed. The internal coat was studded with small calcareous patches, and the two largest, each nearly the size of a shilling, were situated just above the bifurcation.

The left subclavian artery at a point just above its origin is almost blocked by a raised, ragged, calcareous excrescence, as large as a threepenny-bit (calcified atheromatous ulcer). Small atheromatous patches, not calcified, are scattered through the whole length of the aorta, and these, owing to the dark coloration of the tissues, are more easily felt than seen.

The common carotid arteries show small patches of atheroma but the most marked changes are found in the pelvic arteries and in those of the lower limbs.

The common iliac arteries are studded with small patches of atheroma and calcareous degeneration. The other arteries of the pelvis are converted by calcification into rigid "bony" tubes, down to their minute ramifications. So stiff and brittle are they that it was impossible to dissect them out entire, and in spite of every possible care they were invariably broken. The minute intramuscular arteries were easily felt on triturating the muscles under the fingers.

The arteriosclerosis of the ancient Egyptians followed exactly the same course as the disease follows today. The small atheromatous patches and the histological anatomy of the vessels are identical with those of today. The earliest sign of the disease now, as then, is in or close below the fenestrated membrane. The ancient disease, as well as the modern, was characterized by a marked degeneration of the muscular coat and of the endothelium. The small atheromatous patches subsequently fuse and form large patches of degenerated tissue, which may reach the surface and open out into the lumen of the tube.

The etiology of this disease three thousand years ago is as obscure as it is in modern people. The common causes, such as syphilis, tobacco, alcohol can almost certainly be eliminated from the life of the ancient Egyptians. The diet and daily life of the ancient Egyptian people was not such as to bring on this disease and all that can be said is that it was wide spread in young and old, and that three thousand years ago the disease represented the same anatomical characters as it does today.

HISTOLOGICAL STUDIES ON EGYPTIAN MUMMIES

Ruffer's studies on the histology of Egyptian mummies, written at amleh in 1910 and published the following year (1911), form one of he most important contributions to the paleopathology of Egypt. uffer introduced his study with an interesting discussion of the histo- gical methods (Plate LXXVI) he had designed, especially adaptable o the unpromising material, a discussion of embalming procedures, and emarks on ancient evidences of the history of disease in Egypt as ndicated in the papyri. The "papyrus Ebers" contains information egarding intestinal worms, and other papyri relate to medicine but the vidence is uncertain. The works of art, pictures, statues, represent nalformed persons, suggesting disease, and Egyptian temples and ombs contain likenesses of persons afflicted with club foot, rickets and teatopygia.

The first indications that a study of mummies might yield some vidences of the antiquity of disease was the discovery by G. Elliot mith of an ancient gall bladder with biliary calculi. Ruffer then pro- eeded to a careful examination, histologically, of as many mummies s could be placed at his disposal. He studied the skin from mummies Plate LXXVI) 8000-12000 years old, from the XVII-XXth Dynasties nd from Greek and Roman bodies; muscles from the XXIst Dynasty nd from Greek and Roman; nerves from mummies of the XXIst, VIII-XXth Dynasties; blood vessels from the XXIst Dynasty; heart rom the XXIst Dynasty; the liver of Greek and Roman times; kid- eys of the XVIII-XXth Dynasties; lungs from the XXIst Dynasty; ntestines, stomach, mammary glands, and testicles from predynastic imes and from the XXIst Dynasty. The tissues were well preserved, he nuclei clear, since the material had nearly all been fixed by salt olutions used in the embalming processes.

The microscopical examination of tissues from ancient mummies nay reveal pathological changes due to infiltration of tissue by new rowth, infective granulomata, animal and vegetable parasites, in- lammation, proliferation of connective tissue (cirrhosis), atheroma and alcification, but there is little hope of recognizing disease in which the hief lesions are seen in the cells of organs and tissues. The methods f procedure and other details of technique are outlined in the pre- eding section on arterial lesions.

AN ERUPTION RESEMBLING SMALLPOX

In view of Hirsch's suggestion that the Egyptian regions are prob- bly one of the endemic foci of infection of smallpox Marc Armand

Ruffer's (1911.2) discovery of a case of variola, or something very like smallpox, in a mummy of the XXth Dynasty (1200-1090 B. C.) is of extreme interest. The body from which the skin was taken (Plate LXXVII) was that of a tall man of middle age. This body was the seat of a peculiar vesicular or bulbous eruption, which in form and general distribution bore a striking resemblance to smallpox. The piece described and figured by Ruffer was taken from the adductor surface of the right thigh. The eruption as shown in figure c, Plate LXXVII, was a closely set vesicular one.

Microscopic examination of the tissue shows the wavy fibrillae and bundles, but no nuclear staining is discernible. Bacteria are present in great numbers. They seem to be the organisms which produced the infection, but the number of bacteria was doubtless greatly magnified after death.

It would not be at all surprising to find smallpox in Egypt at this time since it has been described as occurring in India and in China as far back as 2000 B. C. Although prior to Ruffer's paper there was no definite information on the existence, in early centuries, of this disease on the African continent.

VESICAL CALCULUS

It is very remarkable that among the many thousands of mummified remains which have been examined from Egyptian graves that so few have shown evidences of vesical calculi. The examination of these bodies was so careful that it is not probable that any examples were overlooked. G. Elliot Smith[6] remarks concerning the scarcity of such evidences:

> The first ancient Egyptian body that I ever saw in situ—at Mr. MacIver's excavations at El Amrah in 1901—was a prehistoric youth with a vesical calculus. Although I have been constantly on the look-out for other examples since then, I have never seen another case, although close upon ten thousand bodies must have been examined either by Dr. Wood Jones or myself in Nubia and Egypt. I have seen two cases of renal calculi, both in Ancient Empire graves in Egypt and one case of gall-stones (in a mummy of the New Empire).

From its very rarity one is forced to conclude that, as compared with their present-day frequency in civilized races, calculi were practically absent among the ancient Egyptians.

EARLY EVIDENCES OF SCHISTOSOMIASIS

One of the most interesting discoveries made by Ruffer (1910.3)

[6] Footnote, p. 56, Bulletin of the Archeological Survey of Nubia, No. 2, 1908.

was the recognition of the calcified eggs of *Bilharizia* (*Schistosoma*) *haematobia* in the kidneys of two mummies of the Twentieth Dynasty (1200-1090 B. C.). At the present time there is perhaps no disease more important to Egyptians than that caused by the schistosomids. So far there is little evidence to show how long it has existed in the country, although medical papyri contain prescriptions against haematuria. The lesions are usually seen in the bladder and rectum, but these two organs are seldom preserved in the mummies. In the kidneys of two, out of six examined, Ruffer was able to demonstrate microscopically a large number of calcified eggs of *Bilharzia haematobia*,[7] situated, for the most part, amongst the straight tubules. Although calcified the eggs are readily recognizable and cannot be mistaken for anything else, proving that renal diseases were not infrequent among Egyptians 3000 years ago.

Malaria is suggested by the discovery of hypertrophied spleens in ancient Egyptians.

RICKETS IN ANCIENT EGYPT

Definite evidences of the occurrence of rickets have not yet been found in the human bodies examined from the ancient graves of Egypt,[8] although Poncet in the memoir by Lortet and Gaillard (1903-1909) on the mummied fauna of ancient Egypt has described rickets in the skeleton of an ape. Wood Jones remarks in this connection:

> Some diseases—notably rickets and syphilis—if at all common, must inevitably have left traces of their presence on the bony structure of the body, and that such traces have not been found in the large series of bodies examined at Biga and Hesa cemeteries, and by Dr. Elliot Smith in other cemeteries in Egypt, is strong presumptive evidence that the diseases did not occur. The infant mortality was apparently a high one, and great numbers of young people, of all ages up to puberty, are found in all the cemeteries, and yet not one of the cardinal signs of the bony manifestations of rickets has been seen in any case.

The occurrence of this disease among modern apes has been discussed by Bland-Sutton[9] and by Frassetto.[10] Poncet's observations on rachitis (Plate LXXXVII) in the mummified apes of ancient Egypt is thus an addition to our previous knowledge. The evidence is to be

[7] F. G. Cowston: Etiology of Bilharziosis in ancient Times. Bilharziosis in Natal. Parasitology, 11, No. 1, 83–93, 1918.

[8] F. Wood Jones—1908—Pathological Report. Bulletin of the Archeological Survey of Nubia, No. 2, p. 57.

[9] (a) Rickets in a Baboon. Trans. path. Soc. London, xliv, 310, 1883.
(b) Rickets in a Baboon (Cynocephalus porcarius), West Africa. Ibid., p. 312, 1883.

[10] Su alcuni casi di Rachitismo nei Primati. Ztschr. f. Morphologie u. Anthropologie, IV, 365–379, 8 figs., 1902.

found in a set of limb bones markedly curved which indicate to this student the occurrence of rickets. His figures are copied herewith.

Among fossil animals older than the ancient fauna of Egypt the disease has been suggested by P. C. Schmerling[11] in the limb bones of a Pleistocene bear from the caves of Belgium, but his evidence is not conclusive.

Among living animals Frassetto[10] has cited the literature in which the occurrence of the disease has been noted in the pig, horse, dog, cat, cow, sheep and goat, domestic birds, the turtle and the primates cited above. Rickets thus seems to have a fairly wide occurrence among recent vertebrates.

APPENDICITIS

Appendicitis has been recorded from the early graves of Egypt by Dr. G. Elliot Smith[12] who has seen evidences of adhesions representing a long standing or chronic condition. These adhesions were seen in the pelvis of an adult woman found in the cemetery at Hesa. The preservation of the internal organs of the bodies found in the cemeteries at Biga and Hesa was often remarkable and allowed some degree of accuracy in the interpretation of the findings. The preservation of the intestinal canal was especially striking. Fragments of the undigested portions of bulky food were commonly found, and the items most readily identified were melon seeds, grape pips, and the husks of barley.[13]

SYMMETRIC OSTEOPOROSIS OF THE SKULL

A nutritional disturbance accompanied by inflammation of the dura mater, evidently having its inception in infancy or early childhood, was doubtless the cause of the development of patches of porous bone seen in the skulls of certain ancient Egyptians. Thus, Adachi[14] has described and figured a skull of a young Egyptian from the ancient cemetery of Siut which exhibits (Fig. *b*, Plate LXXX) on the posterior half of each parietal, removed from both the sagittal and lambdoid sutures by about 2 cm., an elongated, oval area of rounded openings of various dimensions which find their way into the diploë but seldom into the cranial cavity; there being two conditions *Cribra cranii externa* and *interna*, the latter being more frequent.

[11] Recherches sur les ossemens fossiles. Chaiptre XI, Des ossemens fossiles á l'etat pathologique. Liége, 1883.

[12] Bulletin of the Archeological Survey of Nubia, No. 2, p. 55, 1908.

[13] See Ruffer—Food in Egypt.

[14] Adachi, Buntaro—1904, Die Porosität des Schädeldaches. Ztschr. f. Morphol. u. Anthropol., VII, 373–378, 2 pls.

A similar condition is described by Adachi in a recent Dyak skull of middle age, in which the porosities are larger and more developed on the left side. Another example of this condition is described by Hrdlička (1914) from ancient Peru, which is more fully discussed in Chapter XV.

This curious fenestrated appearance (Plate LXXX) is generally known as *Cribra cranii*[15] and is usually associated with the *Cribra orbitalia*,[16] discussed below. Hrdlička (1914) and Koganei[16] suggested a pathological significance for these appearances; Adachi having been uncertain as to its cause, though suggesting pressure atrophy in artificially deformed skulls as a possible cause. Hansemann's report of the occurrence of osteoporosis in modern apes would, however, negate this idea.

Cribra orbitalia[17] is a similar condition of the roof of the orbit, and as in Cribra cranii the porosities seldom penetrate the neural cavity but do communicate with the paranasal sinuses. Rudolf Martin,[15] following Koganei, has tabulated its occurrence among primitive peoples as follows: Socotrans (Arabian descent on island of Socotra near Arabian coast) 47.6%, Negroes of the East Sudan 35%, Malays 22.5%, Ainos 16.8%, Chinese 13.4%, Mongolians 8%, Japanese 11%, in children 27%, in ancient Peruvians 8.9%, in ancient Egyptians 7.1% and in various European races 3.1–4.7%. Hrdlička (*1914, p. 59, footnote*) records the recovery of the two infant skulls with a coral-like osteoporotic development in the roof of each orbit from a XIIth dynasty cemetery in Egypt and Welcker has reported other examples. The osteoporosis (Plate LXXX) appears to be absent in Eskimo skulls and in most white races. Carl Toldt found only 11 examples in an examination of 10,000 European skulls, although Ahrens elsewhere reported 17% occurrence among 470 German skulls examined. Oetteking[18] found 13 cases of Cribra orbitalia in an examination of 182 ancient Egyptian skulls as contrasted with 11% in skulls of recent Egyptians.

These interesting pathological conditions, known as Cribra cranii (parietalia), and Cribra orbitalia (Figure 39) are not to be confused

[15] Martin, Rudolf—1914, Lehrbuch der Anthropologie, p. 620.

[16] Koganei, Y., 1911—Cribra cranii und Cribra orbitalia. Mitt. med. Fak. Univ. Tokyo, X, 113.

[17] Welcker, Hermann, 1888, Cribra orbitalia. Archiv f. Anthropologie, XVII, 1–18 Taf. 1.

[18] Kraniologische Studien an Altaegyptern. Archiv f. Anthropol., xxxvi, 1909.

with the activities of beetles[19] which do produce porosities in ancient skulls, but of such a different character that they are not at all similar. In view of the widespread nature of this pathological condition it may be well here to give Koganei's conclusions from the memoir cited above, as this is the most complete study of the porosities which has yet appeared:

1. Cribra cranii and cribra orbitalia are to be regarded as analogous structures.
2. In a series of numerous examples of Cribra one is able to distinguish three grades; a weak development which takes the form of a plexus of grooves, a median form as the plate-like or sieve-like form and a stronger form in which the plates are united.
3. The most favorable situation for the development of Cribra cranii is the frontal bone; then the parietals and occipitals.
4. The Cribra cranii and the Cribra orbitalia have the closest relationship to vascular furrows; these are especially abundant in the porous field.
5. Both kinds of Cribra are structures which arise by the formation of new bone substance and are to be regarded as osteophytes, related to puerperal osteophytes.
6. The Cribra cranii and Cribra orbitalia are almost equal in their occurrence, both more frequent in children than in adults.
7. In rare cases one finds the Cribra cranii only on the outer surface of the skull.

PROLAPSUS VISCERUM

The condition of the internal organs in many of the bodies from the cemeteries at Biga and Hesa was often surprisingly good, permitting an adequate determination of many visceral conditions. The condition of the rectum and of the vagina found in these bodies is often such that the appearance may be attributed to disease.[20] With the shrinking of the tissues of the pelvis towards their rigid bony supports, the hollow viscera are dragged upon and by a pulling outwards of their walls the cavities of the rectum and vagina are left widely patent. During this process—and before the final drying of the parts—it is not uncommon for the mucous membrane of either or both of these cavities to become everted, and to protrude for some distance outside, and in the final result to simulate very closely indeed a condition of ante-mortem prolapse.

These cases are very common in the early Egyptian bodies and they must not be confused with real prolapse of which only one remarkable example (Plate LXXVIII) was found. The condition presented was one

[19] F. Wood Jones, 1908—Pathological Report, Bulletin of the Archeological Survey of Nubia, No. 2, p. 58.

[20] F. Wood Jones, 1908—Pathological Report, Bulletin of the Archeological Survey of Nubia, No. 2, p. 56.

that must have had its origin before death, for the greater part of the intestine was found extruded from the anus. The prolapse formed a heart-shaped mass that lay pressed against the thighs and extended from the gluteal folds almost to the knees; it was found quite uninjured when the body was unwrapped. The subject of this prolapse was a young girl. One other case in which protrusion of the viscera had probably taken place during life was in a woman found in the cemetery on Biga, in which a stalked body resembling a polypus had prolapsed per vaginam, and had carried in its train a portion of the mucous membrane of the vaginal wall. Similar cases have been met with in older cemeteries containing prehistoric bodies (Plate LXXVIII).

HYDROCEPHALUS IN EARLY EGYPT

The case of Hydrocephalus in an Egyptian of the Roman Period described by Douglas E. Derry (1913) is one of the oldest examples of this deformity. The skull, nearly complete, the pelvis and certain limb bones are carefully described and should be noted in connection with the diseases of the ancient Egyptians. The skeletal parts described belong to a man of about thirty years of age. The teeth were considerably worn, and the individual may have been older than above indicated. The stature was estimated to be 1.506 M. in height. The individual was the victim of some disease of the brain, probably hydrocephalus, which not only caused the excessive growth of the skull but is remarkable for the partial paralysis of the left side, which has left a mark in a very definite manner upon the skeleton of the parts concerned.

The figures of the skull, in the five normae, indicated the deformity of the skull. The mandible was a large, well-developed bone with a prominent chin and a broad, rather low ramus, the angle of which is somewhat everted.

The cerebral disease from which this man suffered was responsible for a condition of hemiplegia affecting the left side of the body, and all of the bones of that side of the body illustrate the changes which such a loss of power entails. The left humerus, apparently normal, shows extensive differences from the right humerus. There is little change exhibited in the ulna. The pelvis is small and deformed, the left side having suffered from the general left-sided lack of development. The index of the pelvic brim, which is only 68.2 shows it to be markedly platypellic, the transverse diameter measuring 110 mm. and the anteroposterior 75 mm. The sacrum shows its irregularity most at the

base, in a general tilting of the body of the first sacral vertebra, accompanied by lessened development of the left side.

The femora and tibiae exhibit similar differences to those shown by the arm bones, accompanied by a slight development of the acetabulum. The dropping of the left side of the pelvis almost certainly necessitated a flexion of the right knee, and the left limb was dragged along as in modern cases of hemiplegia.

A PSOAS ABSCESS—TUBERCULOSIS—POTT'S DISEASE

The mummy (Plate LXXIV) exhibiting the psoas abscess, associated with Pott's disease, or tuberculosis of the vertebral column, was a priest of Ammon of the 21st Dynasty (1100 B. C.), found in 1891 by M. Grébaut in the region of the great Theban city. In 1904 the body, with others, was transferred by order of director Maspero to the Medical School at Cairo, where it attracted the attention of Ruffer (1910.1) and Smith, who have carefully described it, arriving at the conclusion that it is a definite example of tuberculosis (Figure 40) the first one met with in ancient Egypt. The body was that of a young, adult man showing in the lumbar region a very unusual disturbance. The lower thoracic and upper lumbar vertebrae are kinked and necrosed, and on the right side there is a large swelling in the psoas muscle extending into the iliac fossa (Plate LXXIV).

Microscopic examination of the left psoas shows the presence of unmodified muscle fibers, while on the right side there are indications of great disturbance, with numerous calcified leucocytes, embedded with the muscle fibers, together with a lot of trash introduced into the body in the embalming process. The right psoas muscle must have been in semifluid state, as is shown by the embedding of a large amount of material into the fibers of the muscle, indicating a psoas abscess on the point of rupture (Plate LXXIV).

Tuberculosis has been suggested as the cause of ancient lesions in Egyptian human and animal mummies by Poncet, Fouquet, DeMorgan and others but Ruffer and Smith are of the opinion that no true case has been established by them, the majority of their lesions being clearly those of spondylitis deformans.

A PELVIC OSTEOSARCOMA

The bone in which the tumor was found comes from the catacombs of Kom el Shougafa, in Alexandria, and dates most probably from the middle of the third century after Christ. Owing to the fact that the

tombs had been previously rifled and the skeletons in a great disarray no other bones of the skeleton could be identified.

The tumor occupies the right pelvic bone, affecting particularly the ischium (Plate LXXIX) and lower part of the ilium, the pubis apparently normal. The ilium is greatly thickened throughout and the body of the ischium enormously dilated, the enlargement encroaching upon the obturator foramen. The tumor started, doubtless, in the cancellous tissue of the pelvis and its growth has caused a very marked expansion of the bone, deformation of the obturator foramen and encroaching upon the acetablum. There are numerous grooves on the surface suggesting that the tumor was highly vascular. The exact nature of the lesion must remain uncertain but owing to the fact that the swelling is deeply seated, partly solid and partly cystic, and had evidently been growing fast, Ruffer is of the opinion that this tumor was probably an osteosarcoma, of which the bony substance has resisted the effects of time, while its soft parts have disappeared. This is the only known ancient example of an osteosarcoma, unless some of the tumors seen in the ancient dinosaurs are of that nature.

OSSEOUS LESIONS IN EARLY EGYPTIANS

There is a great wealth of material on the osseous pathology of the ancient Egyptians to be gained from the memoirs of Ruffer and Rietti, Derry, Smith, and Jones, and other minor sources of information. A great store of specimens was secured in 1907 and later years when the Egyptian Government decided to make an archeological survey of that part of Nubia which would be flooded more or less permanently when the Assuan dam was raised.[21] The students of medical history were extremely fortunate in this survey since there has been a continuous exportation of Egyptian mummies since the beginning of the middle ages, more than one thousand years, material which was thus largely lost for examination. Many of the lesions described by Ruffer have been placed in the Museum of the Medical School at Cairo.

Spondylitis deformans was extremely common among the early Egyptians, often of a very severe nature, since one vertebral column, described by Ruffer and Rietti, belonging to a man whose name was Nefermaat, belonging to the IIIrd Dynasty (2980-2900 B. C.), from the

[21] The results of these explorations were published in the "Bulletins of the Archeological Survey of Nubia" and in a "Report of the Archeological Survey of Nubia" in folio, from which a great deal of information on the diseases and injuries of the early races of Egypt has been obtained.

fourth cervical vertebra to the coccyx, and possibly through its whole length, had been converted by disease into one rigid block, by the formation of new bone in the anterior spinous ligament (Ligamentum longitudinalis anterius). Distinct bulging of this osseous bridge opposite each space for intervertebral disc allows an examination of the articular surfaces of the vertebrae which are perfectly smooth. The Ligamentum longitudinale posterius was likewise completely ossified although there was no narrowing of the spinal canal.

A less severe case of spondylitis deformans is described in the vertebral column of a woman of the XIIth Dynasty (2000-1788 B. C.), where the disease is localized in the anterior portion of the ninth and tenth thoracic vertebrae.

The disease seems to have had a continuous history in ancient Egypt from very early times. Ruffer and Rietti describe examples of this condition in bodies from the tombs of the soldiers of Alexander the Great and Ptolemy I at Chatby (about 300 B. C.). The early stages of the disease usually show themselves in the dorsal and lumbar regions on the anterior borders of the vertebral bodies on either side close to the middle line. They are characterized by the formation of a small lip which meets a similar prolongation projecting from the adjacent vertebra. Sometimes the new bone spreads as a thick ridge all around the anterior border of the vertebral body and forms powerful masses which may extend over the sides and meeting with similar ridges forms finally a continuous mass of bone. The disease seldom extends to the posterior spinal ligament, and even should the latter become completely ossified, the new bone never intrudes on the spinal canal. The lesions never extend into the substance of the bone but are entirely superficial.

Smith and Jones during the archeological survey of Nubia, prior to the erection of the Assuan dam, examined 6000 bodies, dating from the Predynastic (10,000-3400 B. C.) to the Roman (30 B. C.) periods and reported no traces of syphilis, rickets and only one case of tuberculosis, that of a mummy of a Priest of Ammon of the XXIst Dynasty (1090-945 B. C.) from Thebes which exhibited an extreme form of Pott's disease, associated with a large psoas abscess. Prolapse of the rectum was not uncommon and an exaggerated anal prolapse of the entire viscera was observed in the body of a girl (Plate LXXVIII) of the Byzantine Period, evident as a flattened mass of intestines pressed against the thighs. The abdominal cavity was completely empty. Another woman showed prolapse of the vaginal wall, as well as a

vaginal cyst, 28 mm X 25 mm. Old adhesions due to appendicitis were observed in the pelvis of a young woman of the Byzantine period buried at Hesa. True gout was described and figured in an elderly man. Osteitis deformans was extensively observed, as well as chronic rhinitis, mastoid abscess and periostitis (Plates LXXVII, LXXVIII, LXXXIV, LXXXV).

A Roman skeleton (about 200 A. D.) shows a complete ossification of the ligaments into a solid mass of bone and similar indications are found in a Coptic body (about 500 A. D.) where the vertebrae showed a small amount of overlapping.

The hands of one mummy of the time of the Persian Occupation (about 525 B. C.) showed enlargements of the heads of the first phalanges which may be regarded as Bouchard's nodosities, a malformation which Bouchard has shown to be caused by chronic dilatation of the stomach.

Fractures, with or without callus, are quite common (Plates LXXXII, LXXXIII) being described in a left first rib, tibia and fibula, and a very badly healed leg bone fracture. Smith and Jones have described a number of other fractures and have figured them in great detail.

They figure also an interesting skull (Plate LXXVII) of an ancient Egyptian showing an erosion of the floor of the brain case due to a carotid aneurism.

Caries and alveolar osteitis are frequently met with and Ruffer (1920) has described a number of these cases (Plates LXXXIV, LXXXV) often associated with necrosis of the surrounding bone, as well as by rarefying periodontitis. He made a special study of these diseases (1913.1) in the skeletons found at Merawi representing people of the XXV-XXVIth Dynasties (750-500 B. C., and at Faras of the Meroitic age (100 B. C.-300 A. D.). His study (1913.1) is devoted especially to the teeth on which, in adults, he found considerable wear, evidences of caries and other disorders. There were lesions of the teeth (caries, periodontal disease, alveolar osteitis) in all but two of a series of thirty-six skulls. The lesions were present in the following order of frequency: 1) Impaction, 2) Attrition, 3) Caries, 4) Abscesses and fistulae, 5) Periodontitis and pyorrhea alveolaris. Besides the very bad dentition there were many fractures and Wormian bones were occasionally observed, two bones showed deformities due to rickets, and a series of vertebrae gathered from many places showed a continuous history for spondylitis deformans from 4000 B. C.-300 A. D. Ruffer concludes from

these studies that the people usually did not survive the age of fifty and life for most of them must have been pretty miserable. There are no evidences that dentistry was ever practised. Pyorrhea alveolaris especially seems to be as old as the human race since Ruffer observed evidences of it in skulls of Greek, Roman, Peruvians, Mexicans, Merovingians and Germans.

Thoma, 1916, has studied the evidences of dental diseases in 250 ancient Egyptian skeletons (2000 B. C.) preserved in the Peabody Museum at Harvard University. His results agree with Ruffer's, who says:

The majority of the lesions discovered in the skeletons of old Egyptians, coming from a period extending over more than three thousand years, were typical of chronic arthritis. The spinal column was most often the seat of the disease, the alterations varying from slight overlipping to complete ankylosis, sometimes accompanied by lesions of the sacro-iliac articulation and of the long bones of the lower, more seldom by changes in the long bones of the upper, extremities.

The frequency with which the bones of the hand and foot are affected could unfortunately not be estimated, as, in the majority of cases, it was not possible to say with certainty to what skeleton the bones belonged. Although the number of diseased smaller bones were certainly small, yet it is a peculiar fact that, in almost every case where the whole or the larger part of the skeleton was found, the phalanges were also altered by osteo-arthritis, though the lesions were slight as a rule. On the whole, it would appear that the foot was more often affected than the hand.

Lesions of the carpal bones were never seen, and those of the tarsus were rare.

In many cases the fasciae, the insertions of muscles, or the muscles themselves were certainly invaded by the ossifying process. This is well shown in a skeleton of the IIIrd Dynasty, where a bony mass, which had evidently developed in the muscles and tendons, occupied the vertebral groove. Slighter pathological changes, such as small osteophytes at the insertion of muscles and fasciae (e.g. insertion of the plantar fascia, great trochanter, etc.), though less demonstrative, point to the same conclusion. It is certain also that the lesions were present far oftener than our examination showed, as all the smaller osteophytes, etc. must have been broken off or could not be discovered in the sand of the graves.

The complete or partial ankylosis of the sacro-iliac articulations may be assumed to have been caused by the same disease as the spondylitis deformans. In our opinion it is very doubtful whether lesions such as are shown in some of the bodies should not be classed in separate category. In these cases the pathological process is conspicuous, not so much in the joint as on the flat surface of the bones.

That the old Egyptians suffered from bacterial diseases, identical with those seen now, has been shown by the investigations of Elliot Smith, Ruffer, and Ferguson, but we do not know what was the incidence of such diseases in Egypt. Until that is ascertained, the etiology of the osteo-arthritic lesions of old Egyptians cannot be even guessed at.

Undoubtedly, however, the manner in which the disease spreads along the spine points to its having been due to a chronic infectious process occasionally giving rise to metastases in other articulations.

We could not get any information as to whether the disease was more common in man than in woman.

Certainly the malady was one occurring more frequently in old than in young people. The "determinative" of old age, for instance, in hieroglyphic writing is the picture of a man deformed from chronic arthritis. That it occurred among people in early adult life is shown by the fact that typical lesions were discovered in two young people who had not yet cut their wisdom teeth.

Elliot Smith and Wood Jones have also pointed out the frequency of this disease among ancient Egyptians and have offered other explanations for its cause, indicating as the more favorable one that of environment, saying that "the disease is associated with the country of the Nile Valley, and the mode of life of its population," an explanation rejected by Ruffer. The occurrence of the same lesions in the mummified remains of animals in the arid region removed from the Nile valley[22] and its common incidence among the Pleistocene vertebrates of Europe (Plate VIII) do not favor such an explanation as advanced by Dr. Wood Jones.

Pott's disease was discovered by Ruffer and Elliot Smith in a mummy of the XXIst Dynasty (About 1000 B. C.) (Plate LXXIV), perhaps the earliest landmark in the history of tuberculosis.

As a result of all the osseous lesions with which many of the ancient Egyptians were afflicted there must have been considerable suffering and inefficiency. Ruffer describes one Coptic body (400-500 A. D.) of an adult man, though not old who had extensive dental lesions:

> First right molar extremely carious. In connection with the anterior fang, an abscess had formed which had perforated through the palate into the nasal cavity The track followed by pus is evident and opening into the nasal cavity is nearly the size of a three penny-piece. The dental disease was of old standing. Suppuration had extended backward along the outer side of the gums round the second and third molar teeth in the upper maxilla. . . . Moreover, the fangs of the teeth are exposed through their whole length owing to the absorption of the alveolar walls.
>
> This man suffered also from chronic nasal disease, from arthritis in the glenoid fossa, from periostitis of the great trochanter of the femur, and chronic spondylitis. Racked as he must have been with dental agony, afflicted with a chronic nasal discharge, and stiff with pain in his hip and spine, his life must have been well-nigh unbearable.

[22] In support of this Ruffer remarks (Jour. Path. and Bacteriol., xviii, 160): "The occurrence of spondylitis deformans among ancient Copts is one more proof that the disease has existed throughout Egypt from the remotest times and is independent of climate. It has been found by Dr. Rietti and myself in bodies buried close to the Mediterranean shores, in bodies from Upper Egypt and in Nubia. Quite lately, I have found an example of it in a skeleton from the Meroitic Kingdom (300 B. C.) and buried in the Tropics at Merawi, one of the hottest and driest places in the world, and others in Christian skeletons at Abou Menas and Abou Sir in the comparatively damp region of Mariout. These skeletons date from about 500 A. D."

POLIOMYELITIS

"And Johnathan, Saul's son, had a son that was lame of his feet. He was five years old when the tidings came of Saul and Johnathan out of Jezreel, and his nurse took him up, and fled: and it came to pass, as she made haste to flee, that he fell, and became lame. And his name was Mephibosheth." II Samuel, IV, 4.

Osler[23] says: "Since the days of Mephibosheth parents have been inclined to attribute this form of paralysis to the carelessness of nurses in letting the children fall, but very rarely is the disease produced by traumatism. . . ."

It is true that J. K. Mitchell[24] has given a description of a skeleton of an Egyptian mummy with changes which were supposed to be due to poliomyelitis. Others have described similar deformities in sculptured objects and in paintings; but such deformities, we must acknowledge, might be due either to poliomyelitis or to other lesions of the nervous system occurring in early life. This mummy is in the Archeological Museum of Pennsylvania University, 3700 B. C., found at Deshasheh, 80 m. south of Cairo by Flinders Petrie.

Bones light and fragile from age, small male, 5 ft., 6 in., left leg shorter than right, and left femur lighter and smaller than right, no sign of fracture. Bones of feet unaffected. Bones of lower leg equal. Only one segment, the femoral, affected.

Poliomyelitis, even intrauterine, is suggested as cause of the shortened femur.

Infantile paralysis[25] is apparently represented in a stela of the XVIIIth Dynasty (2000 B. C.) in the Carlsberg Glyptothek at Copenhagen, described by Hamburger (1911). He makes the diagnosis of infantile paralysis on the basis of the "position equine" of the right foot, which shows considerable atrophy from the knee down (Plate LXXV). Many ancient Egyptian statuettes in bronze or varnished earth, representing the gods Bes and Phtah, are accurate figurations[26] of achondroplasia.[27]

Ray and Buxton (1914) in examining material from a prehistoric

[23] Wm. Osler: Principles and Practice of Medicine, N. Y., 1901, 942.

[24] John K. Mitchell: Study of a Mummy affected with anterior Poliomyelitis. Trans. Assn. Am. Physicians, XV, 1900, 134–136.

[25] John Ruhräh and E. E. Mayer: Poliomyelitis in all its Aspects, Phila., 1917.

[26] Garrison, 1917, 1, p. 50.

[27] Charcot: Les difformés et les maladies dans l'art. Paris, 1889, 12–26.

F. Ballod: Prolegomena zur Geschichte der zwerghaften Götter in Aegypten. Munich dissertation (Moscow, 1913).

(700 B. C.) Ethiopian cemetery in southern Sudan, Africa, found evilences of caries, fractures, abscess cavities, a skull with a large osteoma, biliary and vesical calculi, but no evidence of an osteo-arthritis.

TREPHINING IN EGYPT

Very little is known of trephining among the ancient Egyptians, ınd it seems quite probable that it was very little practiced, if at all. Ruffer has described and figured a skull, found at Alexandria and dating rom 200 A. D. which appears to have been trepanned. The edges of he opening have healed over so that the patient survived the operation, but if this is a trephine opening, it is a very poor one.

Another suggestion of trephining in ancient Egypt is given by Proessor Derry, and concerns a circular opening in a skull from Shurafa, ɔwer Egypt, found in a cemetery of Roman date, about 2000 years ld. The skull (Plate LXXXI) is in perfect condition, only a few teeth aving dropped out since removal from the grave, and from its general haracters it is probably that of a young woman of about twenty-one ears of age. In the right parietal bone, close to and involving the ıgittal suture, and situated exactly opposite the obelion, or, in other ords, near the site of the right parietal foramen, is a large hole, measurıg 24 mm in the diameter parallel to the sagittal suture and 26 mm. at ıe widest part of the hole, at right angles to the antero-posterior iameter. The opening is irregularly circular, and is incomplete at s inner margin where it breaks into the sagittal suture. Its edges are erfectly smooth and bevelled externally, and about 8 mm. from the pening there is a faint suggestion of a bony elevation running concenically. Except for vascular pittings over the surface of the skull ıere are no evidences of inflammation.

The skull is markedly flattened (Plate LXXXI) from the hole downards as far as the superior angle of the occipital bone, and laterally volving the posterior-superior angles of both parietals, as well as the ea adjacent to those angles. The depression of the bone, exclusive the hole itself, is greatest immediately below the opening and extly over the posterior end of the sagittal suture; but below the lambda e flattening has affected the right side of the skull more than the left, that the left side of the occipital bone seems to bulge when compared th the corresponding part to the right. It would appear from this at there is some association between the flattening and the perforaon of the bone.

The character of the opening is unlike the trephine openings in

Neolithic skulls, (Plate LXXII) such as those described by Manouvrier. The theory of trephining does not explain the flattening and Derry suggests that the more probable cause of this parietal perforation is a dermoid cyst of the scalp of which a number of examples are known in modern peoples (Plate LXXXI).

LESIONS IN THE MUMMIFIED ANIMALS OF EGYPT

The mummified animal remains preserved in the tombs of ancient Egypt have been carefully described by Lortet[28] and Gaillard and in occasional skeletons they found evidences of disease. In a number of skeletons of baboons, *Cynocephalus* (*Papio*), found in tombs in the valley of Gabânet el Giroud, the long bones show irregular incurvations (Plate LXXXVII) in the arc of a circle, the diaphyses being flattened into the form of a scabbard. The tibia, fibula, humerus, radius all show evidences of rickets of long standing. The curvature of the long bones, their flattening, the swollen appearance of the epiphyseal ends all clearly indicate osseous lesions which survived from the adolescent period.

A series of ankylosed lumbar vertebrae (Plate LXXXVII) Poncet refers to as due to tubercular rheumatism, but the lesions are those of the spondylitis deformans and there is no necessary assumption of tuberculosis. Ruffer (1910.3) and Smith take exception to Poncet's diagnosis and deny the evidence of tuberculosis. The irregular surfaces of the head of the radius and ulna Poncet regards as indicating a sarcoma attacking these bones. The exact age of these remains is not determined but their antiquity is suggested by Lortet's words "The studies of Professor Poncet are of very great interest for they show the presence of rheumatism, sarcoma and rickets thousands of years ago in the baboons."

[28] Louis Charles Lortet, French naturalist and physician, 1836–1909. Trained in medicine Lortet is the author of several important memoirs on paleontology, anthropology, medicine and allied sciences. His most extensive work was that undertaken in connection with Claude Gaillard, curator of the Museum of Natural History at Lyons, of which Lortet was director, on the enormous collection of relics of early Egypt acquired from the tombs of Egypt while Maspero was so actively engaged in the archeological survey of that country. Their studies, issued in three parts under the title "La Fauna momifiée de l'ancienne Egypte" published in the Archives du Museum d'histoire naturelle de Lyon, viii, i-viii, 1–206; ix, i-xi, 1-122; x, 1–336. In these extensive studies are carefully considered all the objects of antiquity collected, chiefly however, the ancient vertebraes of Egypt. In their studies they saw occasional evidences of disease, descriptions of which, by A. Poncet, are included in the work. Lortet was dean of the faculty of medicine at Lyons, and a member of many learned societies. His biography, written by Claude Gaillard is to be found in the Archives du Museum d'Histoire naturelle de Lyon, xi, 1–31, with portrait.

The occurrence of rickets in many species of animals has been ecorded by Frassetto[29] in Turin who has described the effects of the lisease in the skeletons of apes, and, in an extensive bibliography gives eferences to the occurrence of the disease in the pig, horse, dog, cat, x, goat, birds, turtles and primates, and similar results are reported to ave been recorded by P. C. Schmerling (1883) in fossil mammals rom the Pleistocene of Belgium.

SYPHILIS IN EGYPT

The presence of syphilis in early Egypt is still unproven, and its xistence is denied by G. Elliot Smith, F. Wood Jones, Ruffer and thers. On the other hand Fouquet, Jarricot, Lortet and others have uggested its presence and it will be important to give their evidences.

In the large monograph on the mummified animals of Egypt, in he section devoted to anthropology osseous erosions in the skull of young woman found at Rôda suggested to Lortet (Figure 37) the ccurrence of syphilis, although he recognized the possibility of the esions being due to chronic inflammation of uncertain nature, to caries r to tuberculosis. He later supported the idea of these lesions beng syphilitic in two contributions[30] in which he defends the idea very trongly. Fouquet's original paper is given by deMorgan[31] pointing to he prehistoric existence of syphilis, although he has not been supported n this assumption by subsequent workers. The lesions he figured on he prehistoric skull from Amra doubtless may have other explanaions (Plate LXXXVI).

Jarricot[32] also has suggested the existence of syphilis from a study f the features depicted on a small sculptured figure found in Egypt and lating from the Greco-roman period. Berkhan[33] regards the large size of he head in certain Egyptians as pathologic.

[29] D. F. Frassetto: Su alcuni casi di Rachitismo nei Primati. Ztschr. f. Morphol. u. Anhrop., Stuttg., iv, 365–378, i pl.

[30] L. C. Lortet: Crâne syphilitique de nécropoles préhistoriques de la Haute-Egypte. ull. Soc. d'anthrop. de Lyon, xxvi, 211, 1907.

Antiquité du crâne syphilitique trouvé dans la nécropole préhistorique de Rôda Haute-Egypte), 1–12, Lyon, 1908.

[31] DeMorgan: Recherches sur les Origines de l'Egypte, 364, fig. 59, 369.

[32] Jean Jarricot: Syphilis et scaphocépahlie à propos d'une figurine scaphoide de l'anienne Egypte. Bull. Soc. d'anthrop. de Lyon, xxvi, 174.

[33] Oswald Berkhan: Über Makrokephalie in der Familie des Pharao Amenophis IV. 18 Dynastie.) Archiv für Anthropologie, N. F. Bd. XVIII. 155, 6 figs. 1919.

DESCRIPTIONS OF FIGURES 36–41 AND PLATES LXXIV–LXXXVII ILLUSTRATING CHAPTER XIII

FIGURE 36

Sir Marc Armand Ruffer, 1859–1917.

Figure 36

FIGURE 37

Figure 37

Louis Charles Lortet. French naturalist and physician, 1836-1909.

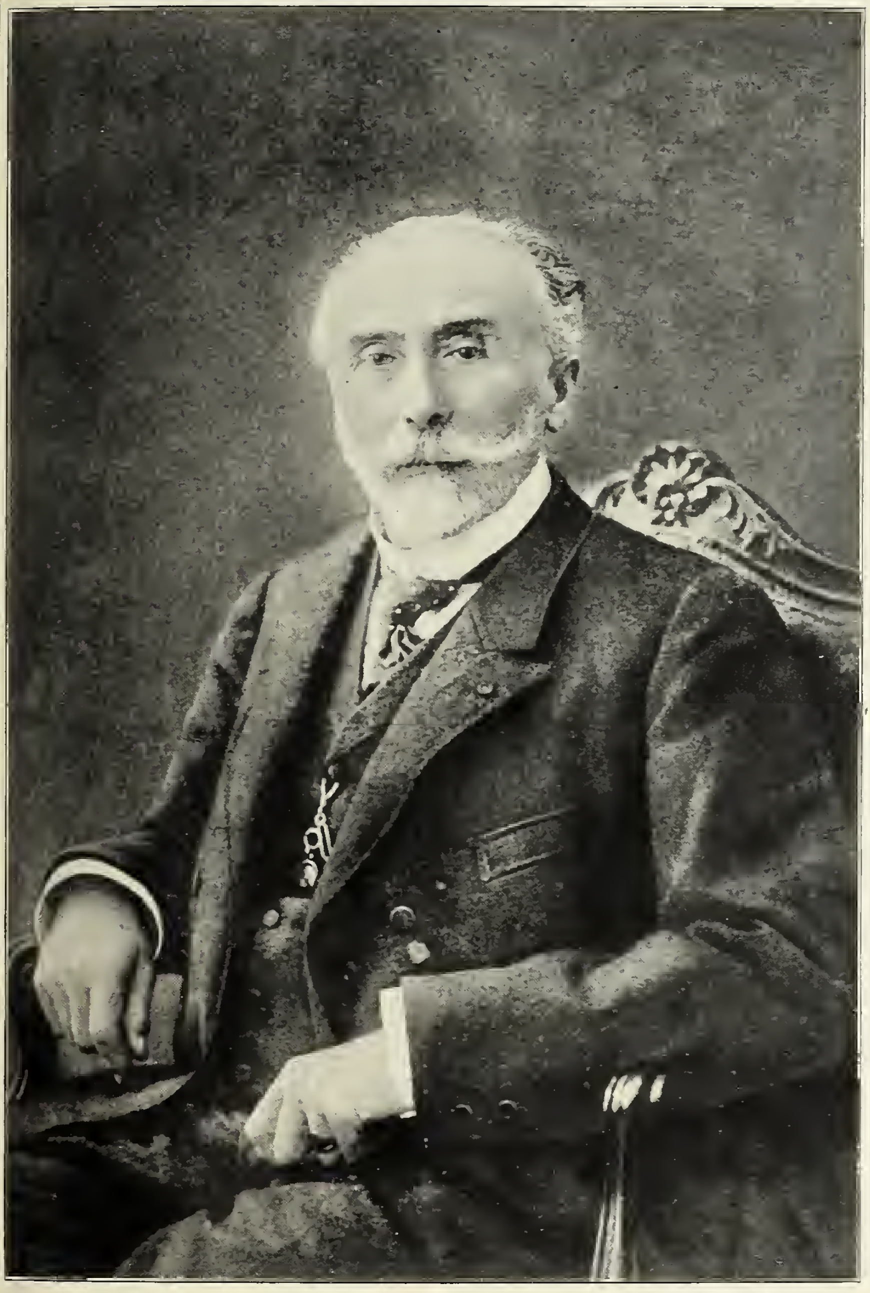


Figure 37

FIGURE 38

FIGURE 38

Map of Egypt showing location of discoveries (marked by a star in a square) which furnished material showing pathological lesions. (Modified from Breasted.)

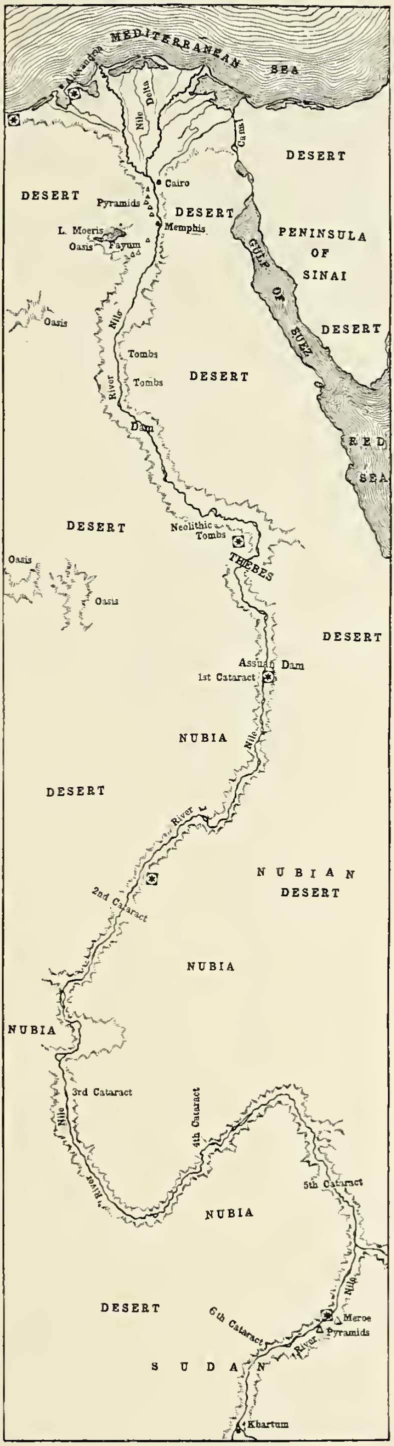

MEDITERRANEAN SEA
Alexandria
Nile Delta
Canal
DESERT
Cairo
DESERT
Pyramids
DESERT
Memphis
L. Moeris
Oasis
Fayum
PENINSULA
OF
SINAI
GULF OF SUEZ
Oasis
DESERT
Nile
Tombs
Tombs
DESERT
River
Dam
RED
SEA
DESERT
Neolithic
Tombs
THEBES
Oasis
Oasis
DESERT
Assuan Dam
1st Cataract
NUBIA
Nile
DESERT
River
NUBIAN
DESERT
2nd Cataract
NUBIA
NUBIA
3rd Cataract
4th Cataract
Nile
River
5th Cataract
NUBIA
Nile
DESERT
6th Cataract
Meroe
Pyramids
River
SUDAN
Khartum

FIGURE 38

FIGURE 39

FIGURE 39

a. Section, somewhat enlarged, of a frontal bone, showing the hyperplasia accompanying the healed lesions in an osteoporotic osteophyte of the pathology known as *Cribra cranii interna*. The upper border of the figure represents the inner skull table. The hypertrophy of the diploic spaces is to be noted. The nature of the disease producing these pathological growths is unknown, but the lesions are probably due to faulty nutrition. The skull from which this section was taken was derived from a female body in a dissecting room. History of the body unknown, but the growths are spoken of as *puerperal osteophytes*.

b. An example of *Cribra orbitalia* in the roof of the left orbit, shown from below, in a recent skull. This is the honey-combed area to the right of the middle of the picture. (Both figures after Koganei.)

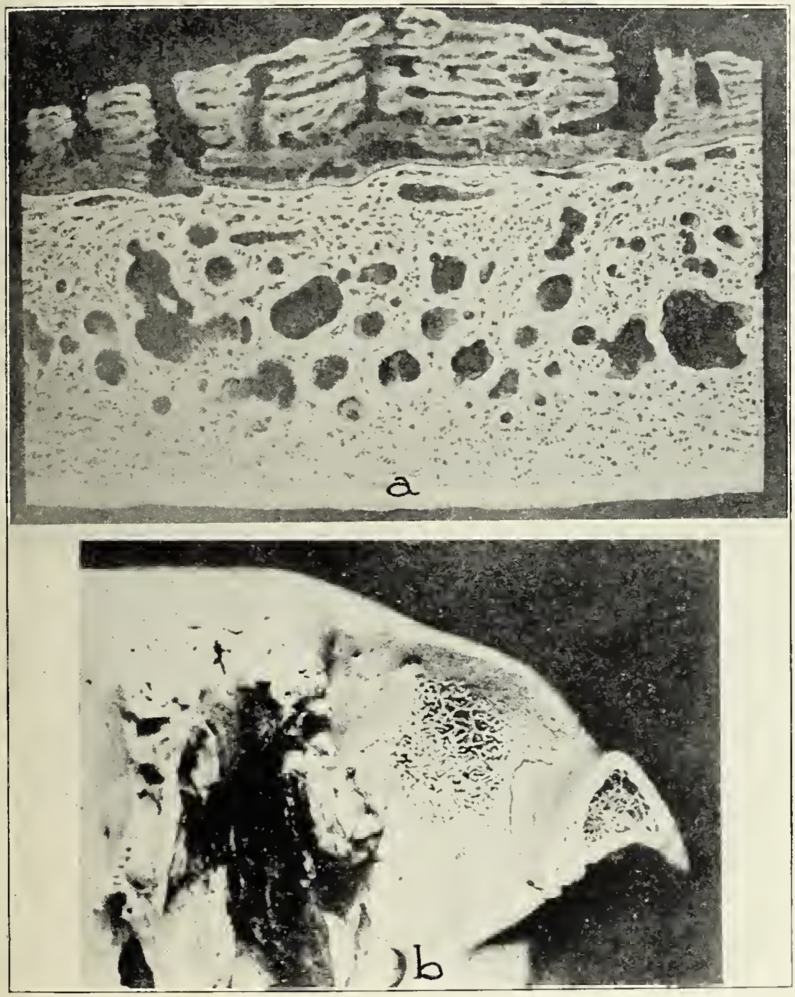


FIGURE 39

FIGURES 40-41

FIGURE 40

Diagram showing three types of abscesses due to vertebral tuberculosis: A, Intercostal or lower thoracic abscess similar to the case shown in the Neolithic example (Plate LXIX, a, c and d.). B, Lower lumbar abscess which passed out into the femoral region through the sciatic notch. C, A psoas abscess penetrating Scarpa's triangle, like the ancient Egyptian example shown in Plate LXXIV. (Modified from Testut and Jacob.)

FIGURE 41

An ancient, predynastic, flint knife found in Egypt, which may have served the ancient Egyptians in their embalming processes. (After Lortet and Gaillard.)

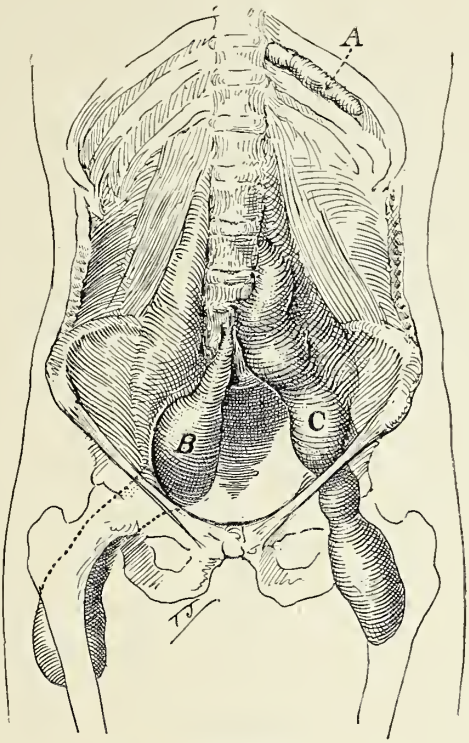


FIGURE 40

FIGURE 41

PLATE LXXIV

PLATE LXXIV

ANCIENT EGYPTIAN WITH POTT'S DISEASE

Mummy of the priest of Ammon, from an Egyptian cemetery of the XXIst Dynasty, (1100 B. C.) showing at the point of the arrow a huge psoas abscess, due to tuberculous infection in the upper lumbar region. (After Smith and Ruffer.)

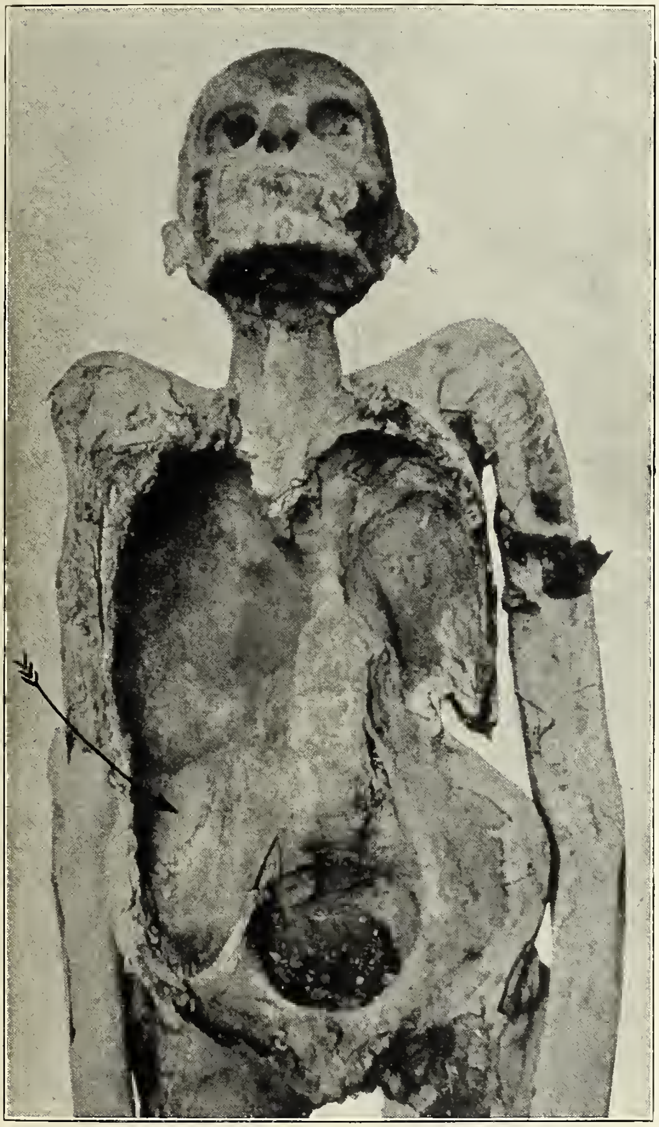


Plate LXXIV

PLATE LXXV

PLATE LXXV

ANCIENT EGYPTIAN PATHOLOGY

a. A stela of the XVIIIth Dynasty (2000 B. C.) in the Carlsberg Glyptothek at Copenhagen, showing in the "talipes equinus" of the male figure evidences of infantile paralysis. (After Hamburger.)

b. Radiograph of buccal surface of jaw.

c. Radiograph of lingual surface of jaw.

d. Mandible of an ancient Egyptian from an Old Empire (Kingdom) (2900 B. C.) tomb excavated by G. A. Reisner at Giza, of a middle-aged male of "The Giza type." This jaw exhibits two perforations to drain an alveolar abscess and possibly represents the oldest example of oral surgery. (After Hooten.)

Plate LXXV

PLATE LXXVI

PLATE LXXVI

MUMMIFIED ORGANS

1. Mummified liver folded upon itself and containing in the cavity so formed a statuette of the human-headed Amset. Nearly natural size.

2. Posterior surface of a mummified heart.

3. Skin of finger. Sweat glands are evident. Nuclei are also seen. Eosin. (Leitz, low power.)

4. Nerve of finger. Haematoxylin. The medullary sheath is well shown (Leitz, Oc. I, X 1–12.)

(All figures after Ruffer in his "Histological Studies of Egyptian Mummies.")

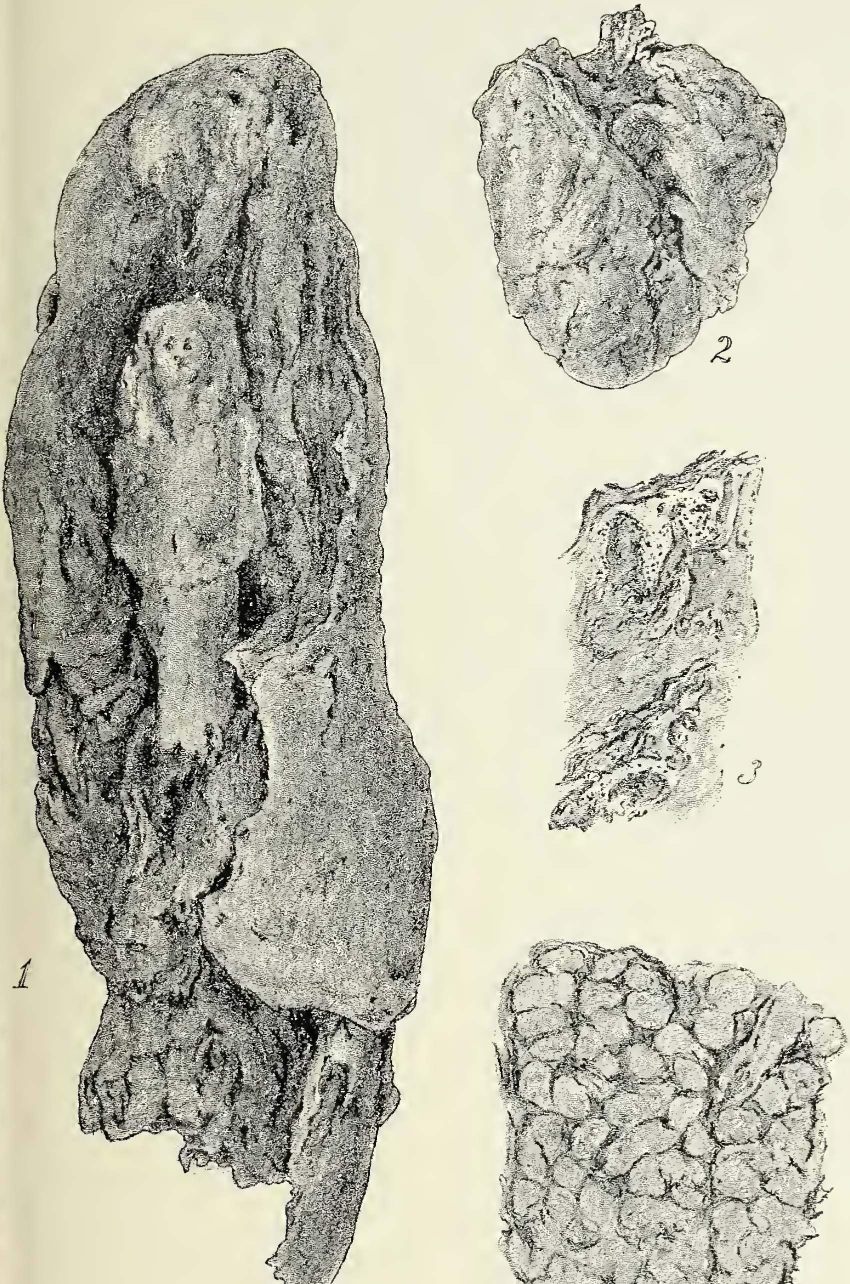


Plate LXXVI

PLATE LXXVII

PLATE LXXVII

ANCIENT EGYPTIAN PATHOLOGY

a. d. e. Femora of soldiers of Alexander the Great, showing lesions of Arthritis deformans. (After Ruffer.)

b. Skull of ancient Egyptian, showing erosion due to a carotid aneurism, at the point of the arrow. (After Smith and Jones.)

c. Portion of the skin of a mummy of the Twentieth Dynasty, 1200–1090 B. C., with an eruption resembling that of Variola. (After Ruffer and Ferguson.)

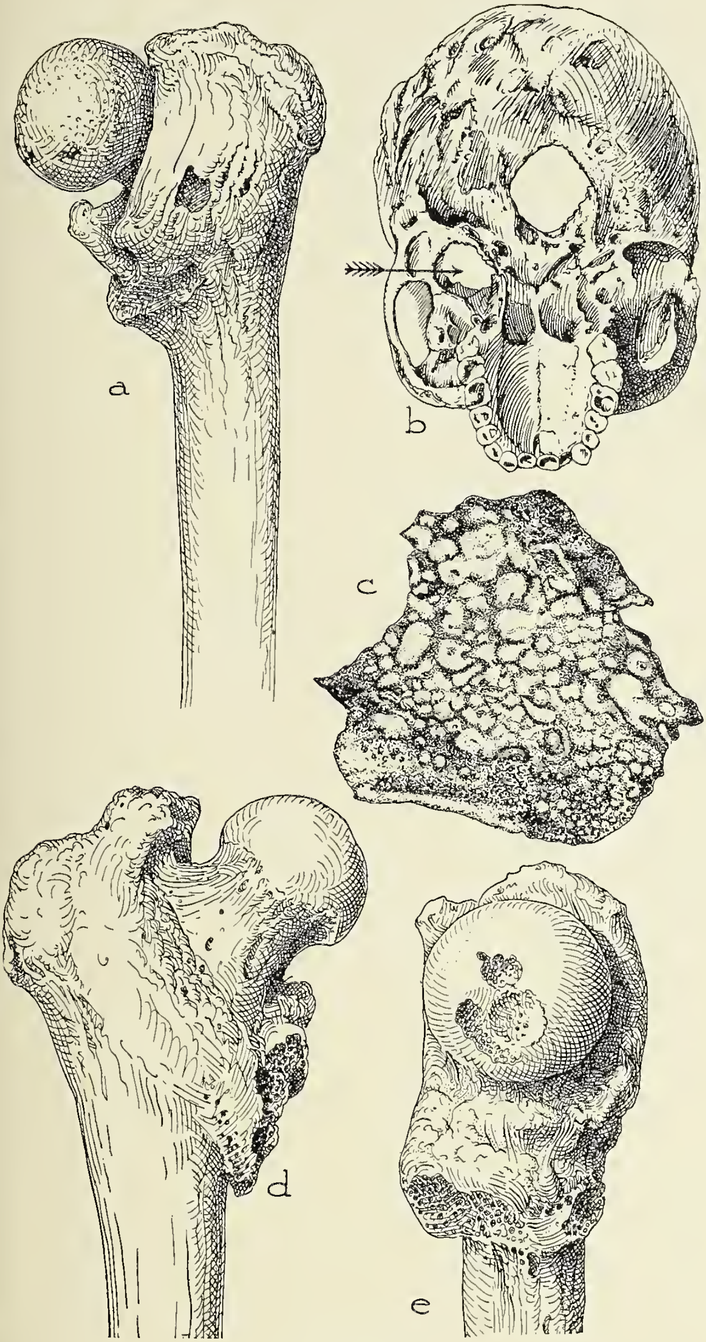


PLATE LXXVII

PLATE LXXVIII

PLATE LXXVIII

ANCIENT EGYPTIAN PATHOLOGY

a. Portion of the body of a girl from the Byzantine cemetery showing anal or vaginal prolapse of the viscera. (After Smith and Jones.)

b. A series of ankylosed lumbar vertebrae, due to osteo-arthritis in an Egyptian mummy. (After Smith and Jones.)

c. A male mummy (Coptic, 400–500 A. D.) showing prolapse of the rectum. A Christian body from Antinoë in upper Egypt. (After Ruffer.)

d. Skull of an Egyptian, showing ankylosis of atlas to skull. (After Smith and Jones.)

e. Maxillary bone of an Egyptian mummy (Coptic 400–500 A. D.), showing the effects of caries and necrosis of the palatum durum. (After Ruffer.)

f. Mandible of an Egyptian (Coptic, 400–500 A. D.) showing the results of caries and pyorrhea alveolaris. (After Ruffer.)

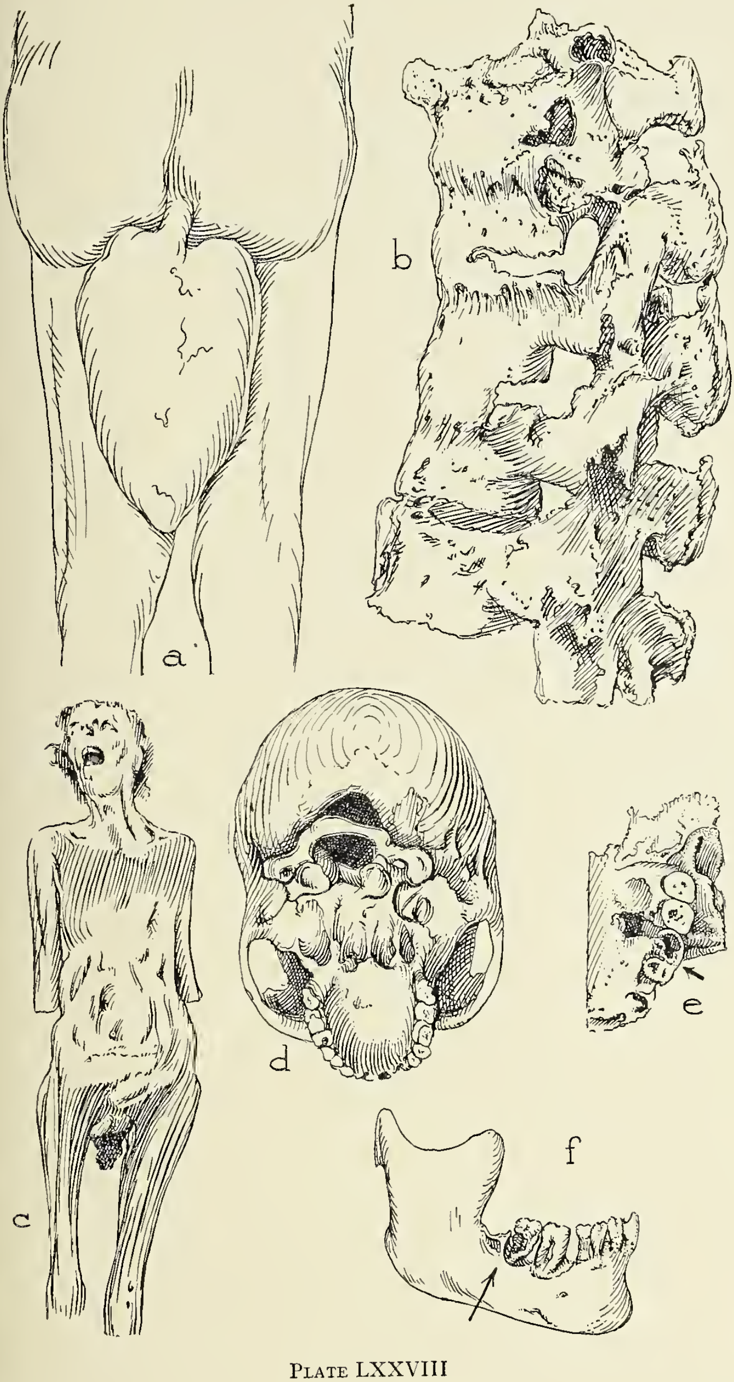


Plate LXXVIII

PLATE LXXIX

PLATE LXXIX

AN ANCIENT OSTEOSARCOMA

An Osteosarcoma in an Egyptian Pelvis

a. Sawn section through the acetabulum, indicating the amount of hypertrophy of the ischium.

b. Median aspect of the right pelvis showing the extent of the tumor, involving the Spina ischiadica, the great portion of the body of the ischium, the acetabulum, the obturator foramen and the lower portion of the ilium. The pubis is apparently normal. The great enlargement seen below the Facies articularis of the ilium indicates the position of the osteosarcoma. The deep grooves on the surface of the ischium suggest a highly vascular tumor.

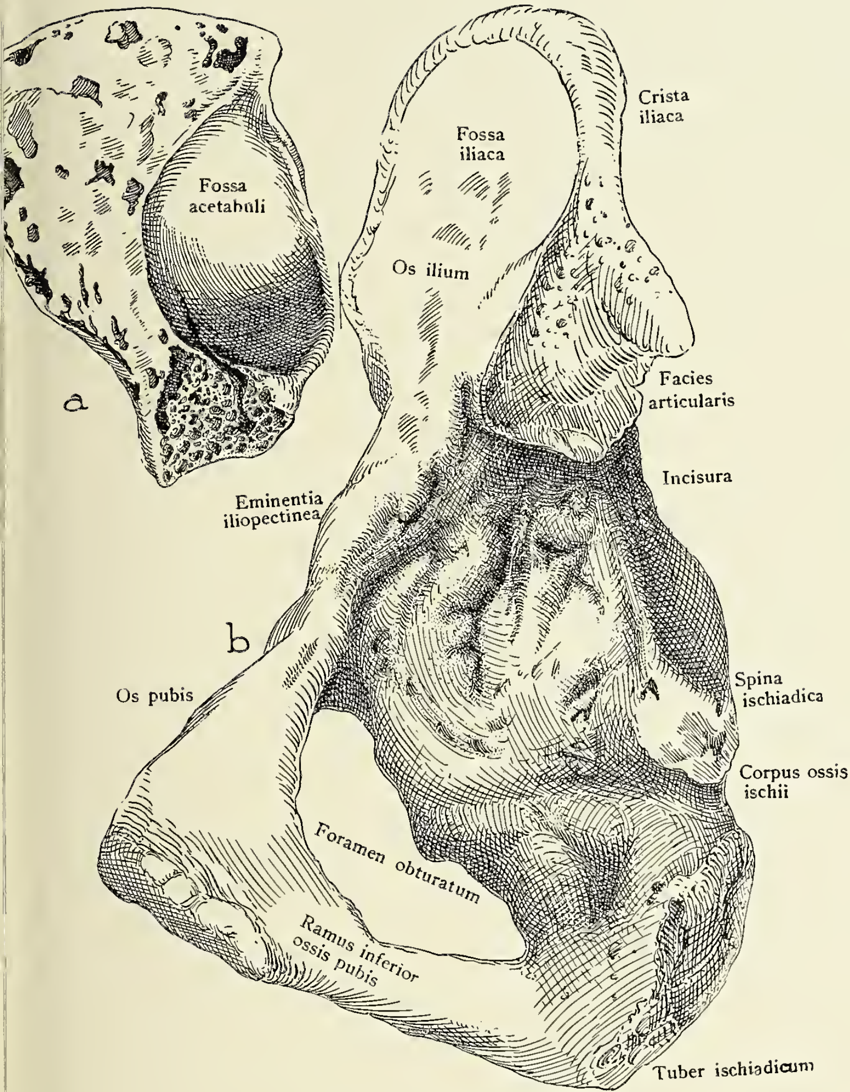

a
Fossa
acetabuli
Crista
iliaca
Fossa
iliaca
Os ilium
Facies
articularis
Incisura
Eminentia
iliopectinea
b
Os pubis
Spina
ischiadica
Corpus ossis
ischii
Foramen obturatum
Ramus inferior
ossis pubis
Tuber ischiadicum

PLATE LXXIX

PLATE LXXX

PLATE LXXX

SYMMETRIC OSTEOPOROSIS

a. Skull of a recent Dyak of middle age showing the healed lesions of symmetric osteoporosis.

b. Skull of a young Egyptian from the ancient cemetery of Siut exhibiting healed lesions of symmetric osteoporosis. (Both figures after Adachi.)

Plate LXXX

PLATE LXXXI

PLATE LXXXI

A DEFORMED SKULL

A skull from Shurafa, Lower Egypt, found in a cemetery of Roman date, about 2,000 years old, of a young woman about twenty-one years of age. A. Right lateral view, showing remarkable parietal flattening, the position of the opening (at the arrow), and the perfect condition of the skull. B. Posterior view, showing perforation suggested to be due to a dermoid cyst, and simulating a trephine opening. (Drawn from photographs by Derry.)

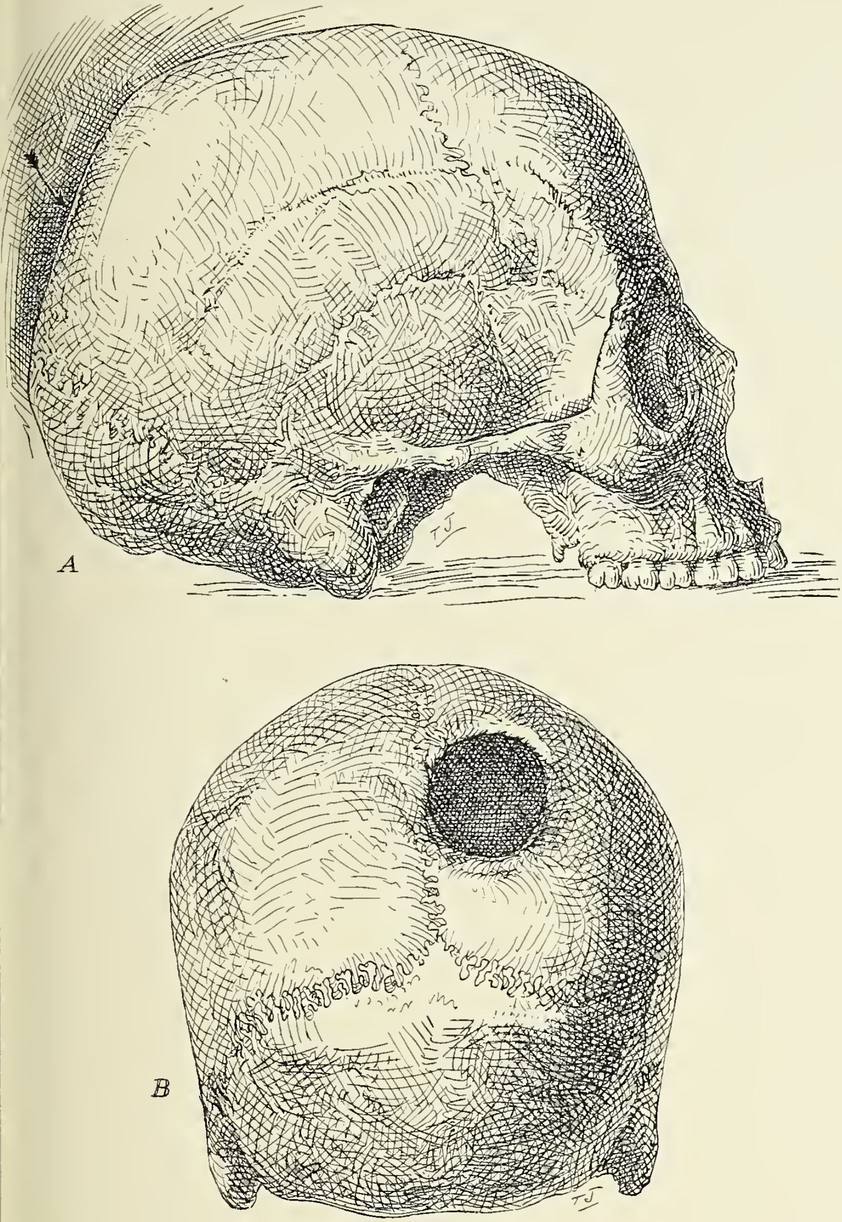


PLATE LXXXI

PLATE LXXXII

PLATE LXXXII

PRIMITIVE SPLINTS

a. Photograph of the most ancient splints as found in position on the bones of a fourteen-year-old girl at Naga-ed-dêr, about 100 miles north of Luxor, Egypt.

b. A primitive set of splints showing the use of palm fiber. The mass of palm fiber adhering to the ulna was introduced to absorb the blood and stop hemorrhage. On the left is a bark splint with blood-stained fiber adhering to its linen wrapping. On the right is one end of a bundle of grass reeds supporting front and back by linen.

c. A set of ancient wooden Egyptian splints (5th dynasty) shown in position around a fractured femur. (All figures after G. Elliot Smith.)

Plate LXXXII

PLATE LXXXIII

PLATE LXXXIII

PRIMITIVE SPLINTS

a. These are the splints shown in Plate LXXXII, *a*, removed from the tomb, cleaned and placed alongside the fractured femur. Note especially the pad of cloth wound around the splint to the left of the fractured femur. The reef knot was used in tying the bandage around the rough wooden splints. The remainder of the cloth had disintegrated.

b. The fractured femur, shown in "a" seen from behind, showing loss of substance and nature of compound fracture.

c. An example of vicious union after fracture of the forearm in an ancient Egyptian. (All figures after G. Elliot Smith.)

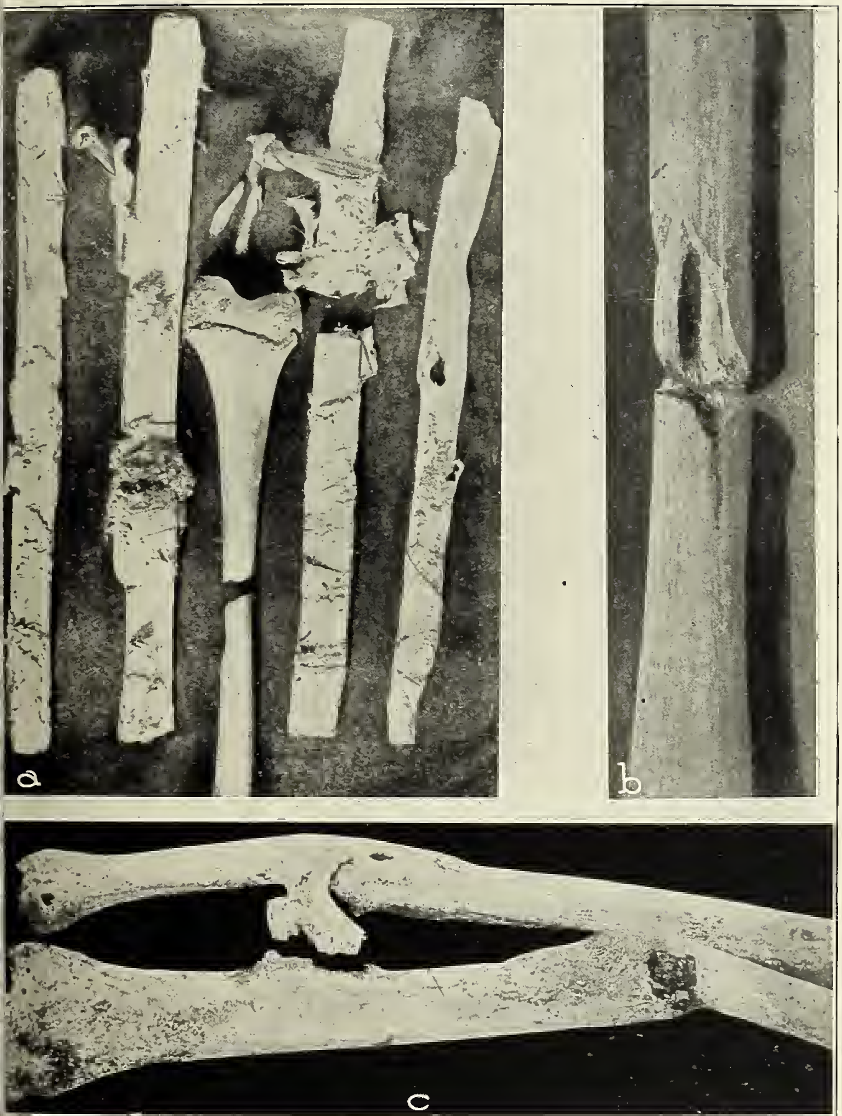


Plate LXXXIII

PLATE LXXXIV

PLATE LXXXIV

ABNORMALITIES AND PATHOLOGY OF ANCIENT EGYPTIAN TEETH

Fig. 1.—From Ras el Tin, Roman Period. Alveolus of a tooth which was irregularly placed. Most teeth lost after death. Right canine and anterior premolar broken probably after death. Molar regions show signs of severe dental and perialveolar disease.

Fig. 2.—Predynastic, Naga el Deir. Alveoli of second molar and posterior premolar absorbed. Crowns of canine and anterior premolar show great attrition, especially on buccal side, whereas in the first molar the center of the crown is the part worn down most deeply. Canine covered with tartar at the neck. Some absorption of the alveoli of all the teeth, most marked round the root of first premolar which is bare for its whole length, and the wall opposite the tip of the root is smooth and rounded. Alveoli round roots of first molar also partly absorbed; that of second premolar almost completely absorbed, doubtless owing to long previous suppuration. Malposition of third molar.

Fig. 3.—Cleopatra's period. Faulty implantation of third molar. Alveolus of second molar completely absorbed.

Fig. 4.—Pyramid period (?). Some malposition of third lower molar; corresponding maxillary tooth is much smaller than its neighbor. Mandibular molars somewhat bare and with distinct pitting of alveolar border.

Fig. 5.—From Ras el Tin, Roman period. Second lower molar shows small oblong enamel nodule. Some absorption of alveolar wall of same tooth.

Fig. 6.—A Gizeh pyramid-builder. Abnormal position of teeth and alveolar absorption. (After Ruffer.)

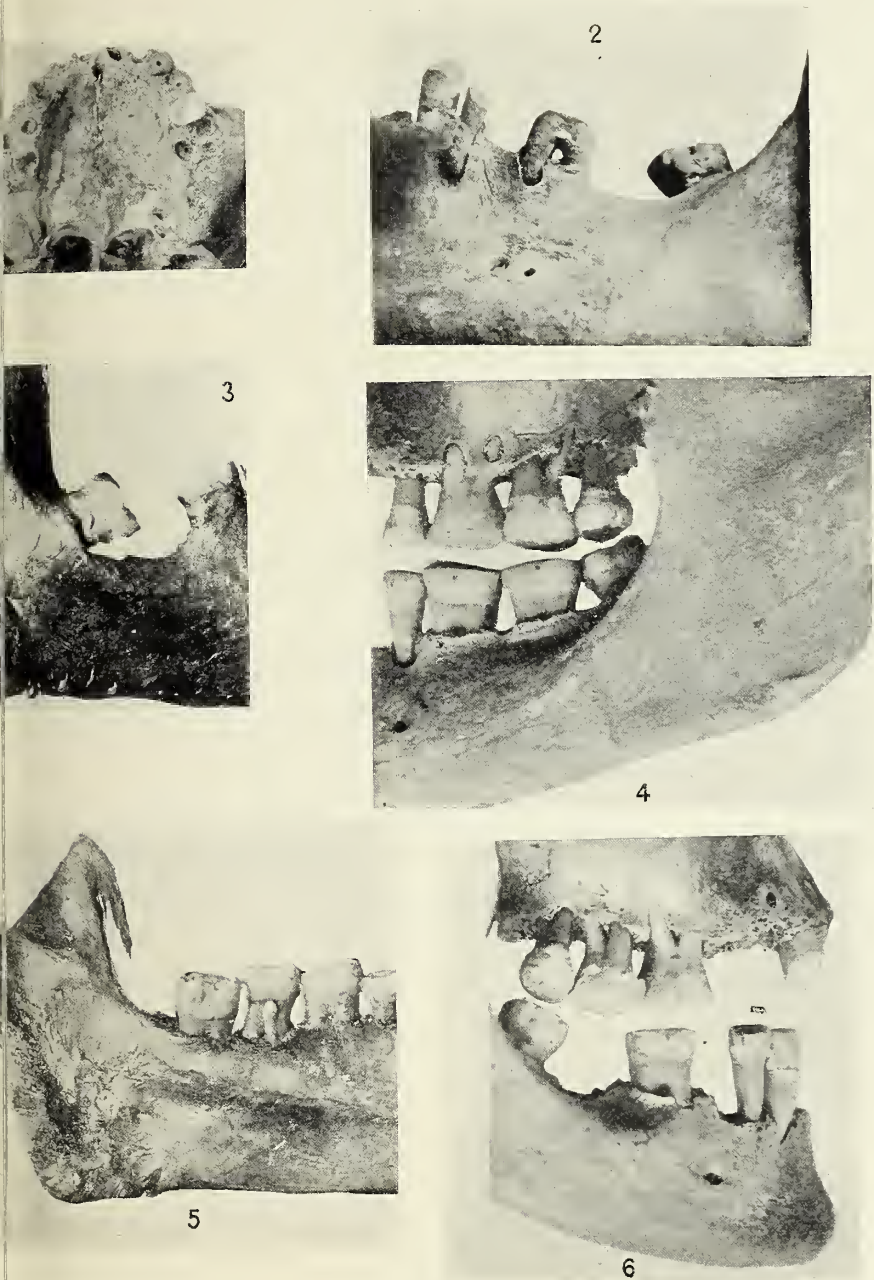


Plate LXXXIV

PLATE LXXXV

PLATE LXXXV

ABNORMALITIES AND PATHOLOGY OF TEETH IN ANCIENT EGYPTIANS

Fig. 1.—Coptic skull. All roots exposed. Lower third molar lost during life, its alveolus completely absorbed. Second molar has deep carious cavity on buccal side of root. Alveoli of second and first molars completely absorbed on buccal side, probably owing to long-continued suppuration.

Fig. 2.—Predynastic, Naga el Deir. "a" indicates perialveolar inflammation. Pyorrhea and periodontitis.

Fig. 3.—From a pan grave, Ballalish. Deep seated abscess connected with alveolus of lateral incisor, perforating through the palate into mouth.

Fig. 4.—Cleopatra's period, Ras el Tin. First molar wholly bare, owing to chronic rarefying periostitis. Roots of premolars partly bare; second and third molars nearly normal.

Fig. 5.—Cleopatra's period, Ras el Tin. This mandible displays a huge alveolar abscess.

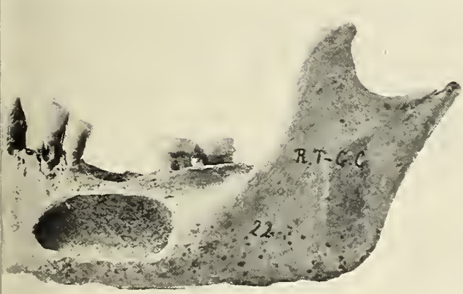
Fig. 6.—Predynastic, Naga el Deir. Shows marked signs of infections. (After Ruffer.)

1

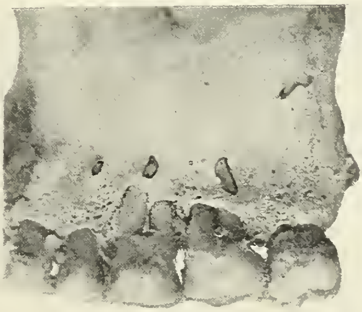
2

3

4



5



6

Plate LXXXV

PLATE LXXXVI

PLATE LXXXVI

ANCIENT EGYPTIAN PATHOLOGY

a. Skull of a young woman, supposed by Lortet to be syphilitic, from the ancient cemeteries at Rôda. The scale-like lesions on the outer table accompanied by cranial hypertrophy, are often seen in modern calvaria from dissecting rooms. Their etiology is uncertain.

b. Skull of a baboon, *Papio hamadryas*, showing in the symmetric hypertrophy of the cranial bones the condition often seen in human skulls due to Paget's disease, more generally known as osteitis deformans, Leontiasis, and often confused with acromegaly. The cranium is one of a vast number of mummified apes described by Lortet and Gaillard in their magnificent memoir.

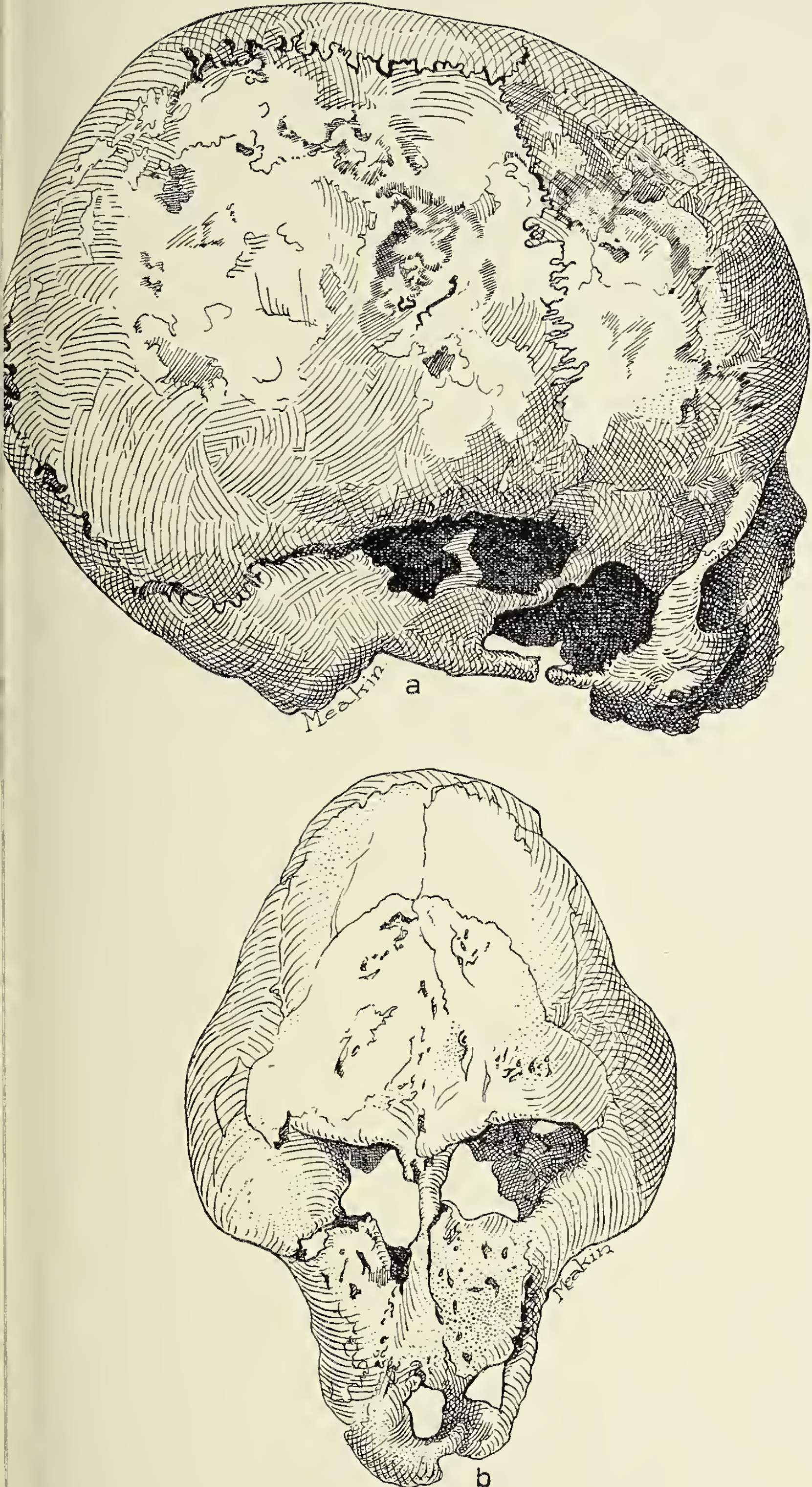


Plate LXXXVI

PLATE LXXXVII

PLATE LXXXVII

ANCIENT EGYPTIAN PATHOLOGY

a. and *b.* Left femur and tibia of a baboon, showing what is regarded by Professor Poncet as the results of rachitic deformation. This is the oldest example of rachitis described adequately. Schlosser has mentioned the bones of a cave bear which appear to indicate rickets but they have not been described.

c. Right humerus of a baboon showing similar deformities.

d. Portion of the lumbar region of the vertebral column of a mummified ape, showing lesions of spondylitis deformans.

All specimens from ancient Egyptian cemeteries and all figures after Lortet and Gaillard.

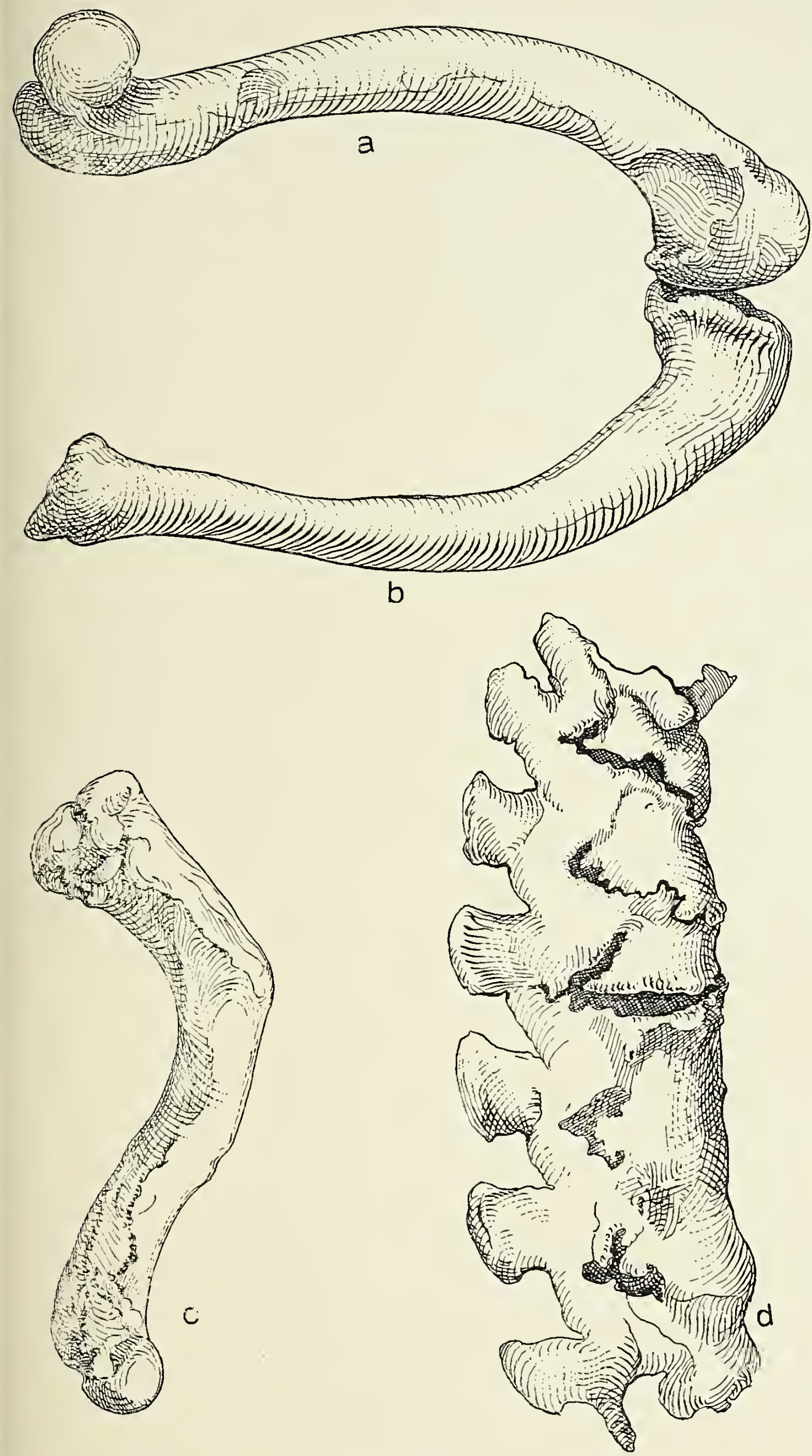


Plate LXXXVII

CHAPTER XIV

DISEASE AMONG THE PRE-COLUMBIAN INDIANS OF NORTH AMERICA

Evidence of Pathology among American Aborigines. Knowledge of Surgery. Descriptions of Figures 42-45 and Plates LXXXVIII-XCVII illustrating Chapter XIV. Figures 42-45 and Plates LXXXVIII-XCVII.

There is considerable evidence to show that many diseases prevailed among the Indians north of Mexico prior to the advent of the white people. The condition of the skeletal remains, the testimony of early observers, and the present state of some of the tribes in this regard, however, warrant the conclusion that on the whole the Indian race was a comparatively healthy one. It was probably spared at least some of the epidemics and diseases of the Old World, such as smallpox and rickets, while other scourges, such as tuberculosis, syphilis, (pre-Columbian), typhus, cholera, scarlet fever, cancer etc., were rare, if occurring at all.

Our knowledge of the antiquity of man on the North American continent is limited to the rather indefinite testimony furnished by tradition, by the more definite but as yet fragmentary evidences of archeology, and by the internal evidence of general ethnological phenomena. No one can speak with assurance, on the authority of either tradition or history, of events dating back further than a few hundred years, and the highest estimates do not exceed a few thousand years. There is no definite accepted chronology, such as exists for the Egyptian peoples. Careful researches by Hrdlička have shown conclusively that no human remains of any great antiquity have as yet been discovered on this continent and there seems little chance of their occurrence in this region.

The erection of the mounds by the mound builders probably was continued for many hundred years and did not end until after the advent of white men. The mounds vary in extent, measuring from a few feet to 1000 feet in diameter, and also in mode of construction and contents. Many of the data on pathological lesions given below are based on material obtained from these mounds.

Data regarding the skeletal lesions of the North American Indians are relatively rare, and are to be found scattered throughout a wide range of anthropological literature and on material contained in many museums. For guidance in the search for the evidences given below I am indebted to Dr. Aleš Hrdlička, who has written more than any other student on the diseases of the North American aborigines. Under his supervision there has been assembled at San Diego, California, a large collection of early Indian skeletal remains illustrating this phase of Paleopathology. A catalogue of this important collection has been prepared but not yet printed. Dr. Hrdlička's papers, in which there are references to early pathology, are listed in the bibliography. Other writers on the Paleopathology of the early races of North America are Parker, Orton, Langdon, and reviews by Fletcher, Lamb, Hyde, Morgan, Bloch, Virchow, and Buret.

EVIDENCE OF PATHOLOGY AMONG AMERICAN ABORIGINES

The pre-Columbian Indians of North American suffered from a variety of injuries and disease, many of which resulted in surgical conditions. Whitney[1] has discussed these in his excellent contribution to paleopathology, in which are described a variety of traumatic conditions, such as skull fracture, arrow-point wounds, fracture of the clavicle, arm, femur, as well as luxation of the hip, congenital and otherwise. Among the constitutional affections he mentions a variety of exostoses, periostitis, arthritides, caries and doubtful evidences of syphilis.

It is curious to note that there are in the Peabody Museum, Harvard University, found in the stone graves of children in Tennessee, Arkansas and Missouri, little clay images (Plate XCI) which are faithful representations of persons affected with Pott's disease, and that many of the water-bottles from the stone graves of Tennessee and from the mounds of Missouri represent women with hunchbacks. Pott's disease is seldom indicated on skeletal remains and it is possible that the clay images do not indicate any great prevalence of vertebral tuberculosis in these localities, but represent other spinal deformations.

The skeleton of an adult and a portion of the lower jaw of an infant were discovered near Lansing, Kansas, in February 1902. There has been considerable discussion of the antiquity of this skeleton but

[1] Whitney, William F.: 1886, Notes on the Anomalies, Injuries and Diseases of the Bones of the Native Race of North America. Peabody Museum Reports, iii, 433–448.

there seems to be no proof that it is very ancient. Hrdlička[2] is of the opinion "that the Lansing skeleton is practically identical with the typical male skeleton of a large majority of the present Indians of the Middle and Western states."

The skeleton, whatever its age, shows evidence of arthritis deformans with interesting lesions, described by Dr. Charles Parker (1904).

Langdon (1881) examined 662 skeletons of "pre-Columbian" (?) Indian skeletons and has devoted a special section of one of his studies to pathology. A nearly entire series of vertebrae was ankylosed by spondylitis deformans. Other bones showed extensive osteo-arthritis of the jaw, vertebrae, ribs, ilia, and carpals. Periostitis, osteitis, osteomyelitis, hyperostoses, and other evidences suggested syphilis. Of 141 crania examined only eleven exhibited fractures, which in a war-like people, is very unusual.

Syphilis among pre-Columbian races (Figure 42) of North and South America is still a mooted question and has been discussed by a number of writers. Jones[3] suggests this disease as the cause of certain pathological changes in the bones of the aborigines of Tennessee. Bloch has reviewed the entire question of prehistoric and pre-Columbian syphilis, with no definite conclusion reached. Hrdlička regards the evidence as still inconclusive (see Plate LXXXVIII).

KNOWLEDGE OF SURGERY

Surgery among the pre-Columbian Indians north of Mexico was in a comparatively rude state of advancement. They were still in the stone age of culture, and really knew less about surgical procedures than many other races of similar progress. A variety of minor surgical operations was known to them. Major surgery was an unknown field, being indicated only by a few examples of trephined skulls found in northern Mexico. They removed small tumors, and appear to have been versed in the use of ligature, using in late centuries horsehair for this purpose. Bloodletting, which they doubtless acquired from the whites, was extensively employed, irrespective of the disease. They used a sharp-pointed flake of flint for opening veins, like the one figured on the right in Figure 43. This was often attached either by a rawhide or, later, by an iron pin to a wooden handle. The blood was usually taken from the seat of disease. In severe cases of pains in the head they

[2] Aleš Hrdlička: Skeletal Remains suggesting or attributed to early Man in North America, Bull. 33, Bur. Am. Ethnol., Wash., 1907.

[3] J. Jones: Explorations of the Aboriginal Remains of Tennessee. Smithson. Contrib. to Knowl., Wash., 1876, 49, 61, 65, 73, 85.

opened the temporal or posterior auricular vein or artery instead of trephining, as did many of the European peoples in Neolithic times.

The Indians were really skillful in the use of splints for fractures, and they developed a variety of forms of protection for the injured member. They were much further advanced in this regard than the ancient Egyptians. How much the knowledge of treatment of fractures among the Indians was due to the influence of the whites is impossible to say. The evidence points to some pre-Columbian knowledge of the subject. A particularly well healed tibia is shown in Plates XCIV and XCV. A primitive form of splints is shown in Figure 43. These were curved pieces of bark, either cut to fit the limb or else padded with wet clay, which on hardening, made a very good support. This parallels and was almost as good a support as a plaster-of-Paris cast. If nothing better offered, strips of wet rawhide were bound tightly around the wounded member. When dry this would make a firm support. Another favorite splint very frequently used was made of a number of thin, light slats fastened together with a buckskin thong, so that the slats are all parallel, and about their own width apart. The flexible lattice work was properly padded and wrapped about the limb. The slats at either end of the splint were drawn together and tied, thus forming a light dressing for many types of injuries. This splint was often used for the prevention of movement of rheumatic limbs. The presence and virulence of arthritic infections are indicated by the lesions preserved on the skeletons.

The North American Indians were also skillful in devising supports for injured members. A rude form of crutch is shown in Figure 43. They strapped the mammae in the case of abscesses and bandaged the thorax in all pulmonary inflammations. A flint knife, such as the one shown on the right, was used in opening abscesses and boils. The pus was generally removed by sucking, either directly with the mouth or through a reed. The peculiar wooden instruments shown (3, Fig. 43) are said by Freeman to have been used in cupping. The smaller instrument is a Cliffdweller's stone pipe used in the suction treatment of abscesses and suppurating wounds. Buffalo horn and other hollow objects were also used.

Amputation may have been occasionally employed, the bleeding being stopped by hot stones. The use of the tourniquet was undoubtedly slightly understood, and other coagulants, such as spider webs and the fine fibers of plants, were employed. Operations for the

removal of the pterygium was probably the only knowledge of ophthalmology among the Indians.

The knowledge of anesthetics among the pre-Columbian Indians was not extensive, though they knew the use of certain substances. The Zunis and other tribes employed a substance obtained from the jimson weed (Datura meteloides), containing stramonium. It was administered in sufficient quantities to produce indifference to pain or even complete unconsciousness, and in this condition abscesses were opened, fractures set, dislocations reduced, and other surgical procedures accomplished. This, according to Freeman, represents the knowledge of the Indians in modern times. It doubtless merely suggests the state of knowledge among the more ancient peoples who inhabited this continent. In this connection may be also mentioned the psychic states induced by the medicine men with their bizarre make-ups, weird incantations, and fantastic antics, all of which were well calculated to make a profound inpression on their credulous patients.

Trephining was practised among the Tarahumare Indians (Figure 45) of Chihuahua in northern Mexico, but this did not spread north of the Rio Grande. The few examples known are doubtless to be traced to influence emanating from Peru, where trepanning was extensively performed.

DESCRIPTIONS OF FIGURES 42–45 AND PLATES LXXXVIII–XCVII ILLUSTRATING CHAPTER XIV

NOTE: A large collection of supposedly pre-Columbian Indian remains was loaned the writer for a long period of time by Dr. Sullivan of the American Museum of Natural History. The following plates represent the results of my study of this collection. These figures form an important contribution to the Paleopathology of the pre-Columbian North American Indians.

FIGURE 42

a. Portion of frontal of a pre-Columbian North American Indian showing perforating injuries.

b. Inner view of a skull with a perforating injury, possibly to be attributed to an arrow-point. (After Fletcher.)

c, d, and *e.* Cross-sections through tibiae of supposedly syphilitic bones of pre-Columbian Indians from mounds in the Ohio valley showing sclerosis and porosis in walls. The medullary cavities are almost filled with spicules.

f. A cross-section of a recent tibia for comparison with the ancient diseased bones. (After Orton.)

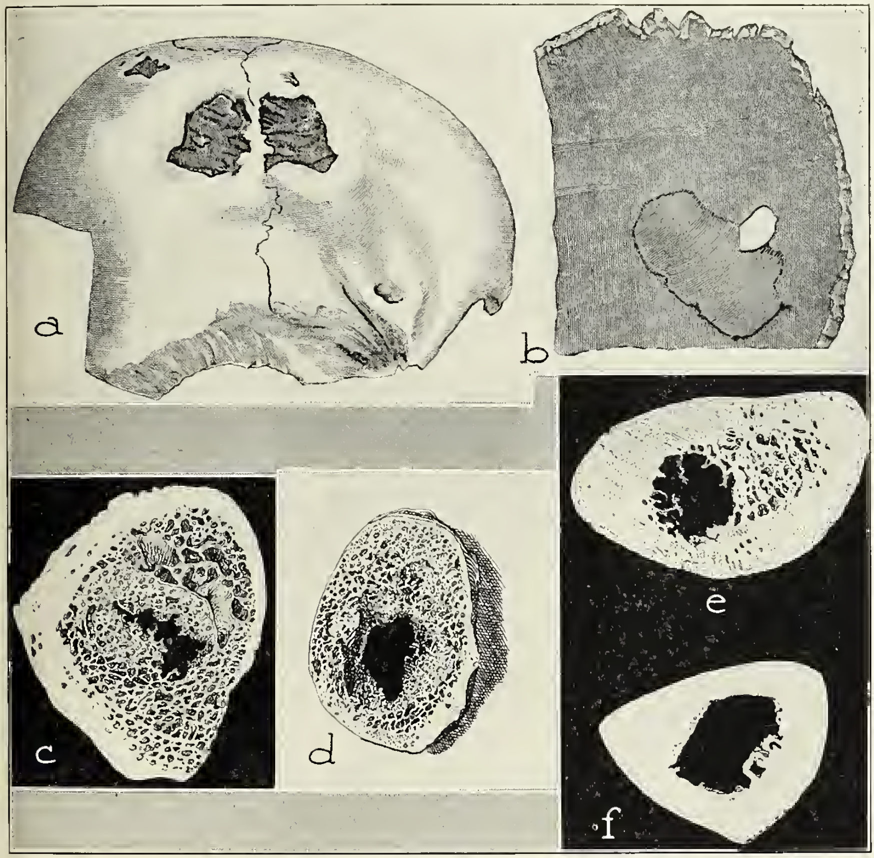


Figure 42

FIGURE 43

FIGURE 43

1. Splints of bark found in an ancient cliff dwelling of southwestern Colorado. These were padded with wet clay and fitted to the fractured limb, then bound with rawhide. (After Freeman.)

2. Crutches found in cliff dwelling of southern Utah. They may be due to the influence of the whites, though the primitive Indians were skilful in devising supports for the injured. Originals in Field Museum. (After Freeman.)

3. The larger is a peculiar wooden instrument with cupped end, and a hole on one side slanted upward, into which a hollow reed could be inserted. This instrument was possibly used in cupping, by pressing the hollowed out end against the skin and sucking out the air through the reed. The smaller object is a Cliff Dweller's stone pipe which may also have been used in cupping and the suction treatment of abscesses and suppurating wounds. (After Freeman.)

4. The object on the left is a sharp-pointed flint flake such as the primitive Indians used in opening a vein or an abscess. The one to the right served as a knife. Such flint flakes are very common in archeological collections. It is not probable that the Indians designed implements exclusively for surgical purposes.

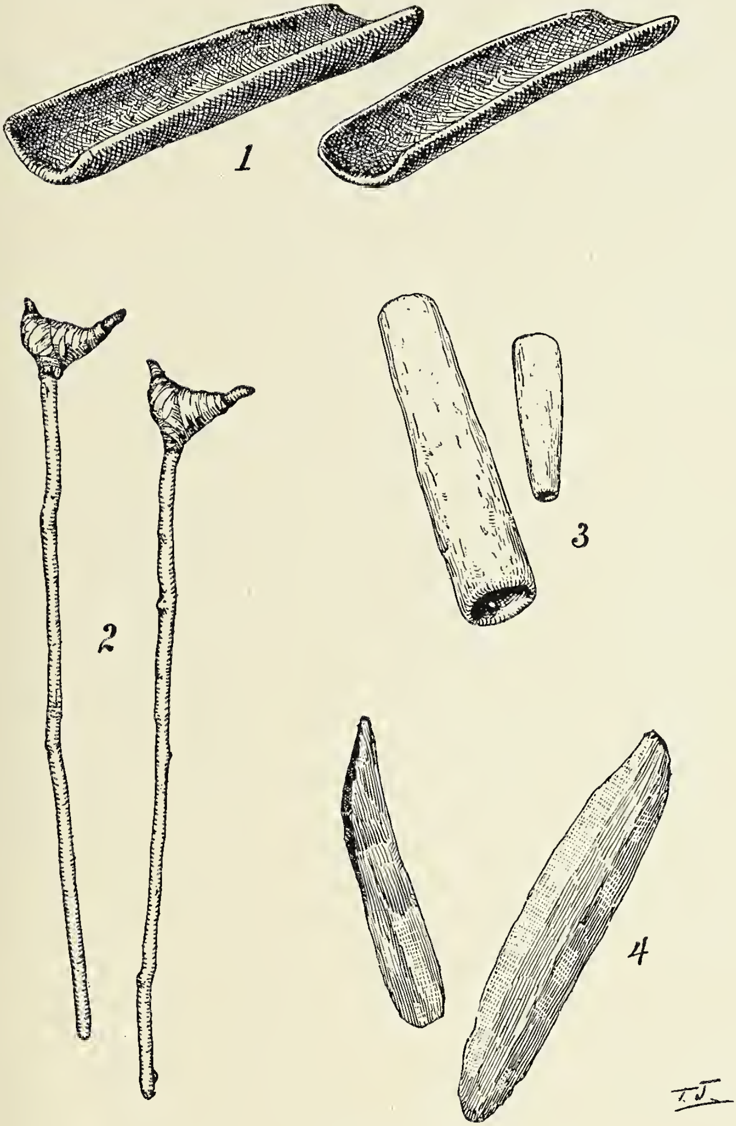


FIGURE 43

FIGURE 44

FIGURE 44

A bark (orthopedic?) corset doubtless used for treatment of spinal lesions and suggesting considerable knowledge of spinal disturbances. Used by the primitive Indians of western North America. (After Freeman.)

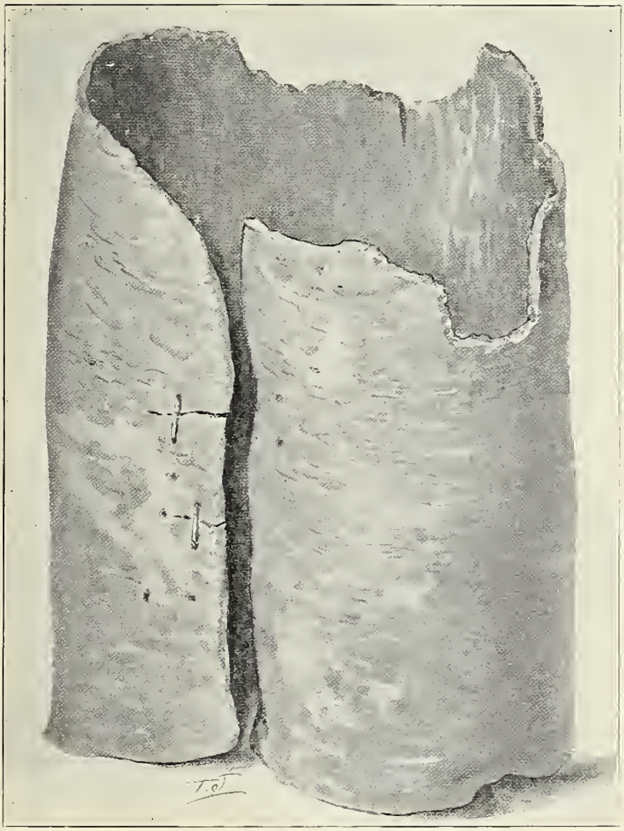


Figure 44

FIGURE 45

FIGURE 45

Map of North America showing distribution of Indian tribes. (Courtesy of Dr. Clark Wissler.)


ESKIMO I
ESKIMO II
ESKIMO III
ESKIMO IV
ESKIMO V
ESKIMO VI
ESKIMO VII
ESKIMO VIII
KHOTANA
AHTENA
LOUCHEUX
HARE
NAHANE
STRONG-BOW
DOG-RIB
YELLOW KNIVES
CARIBOU-EATERS
NASKAPI
TAHLTAN
SEKANAIB
SLAVEY
BEAVER
CARRIERS
HAIDA
CHIMMESYAN
BELLA BELLA
BELLA COOLA
TCILKOTIN
CHIPEWYAN
CREE
SWAMPY-CREE
KWAKIUTL
COMOX
THOMPSON
LILLOOET
SHUSHWAP
NOOTKA
CHIMAKUAN
MAKAH
COWICHAN
OKINAGAN
METHOW
SQUAMISH
TWANA
NISQUALLI
CHEHALIS
SARSI
BLACKFOOT
KUTENAI
BLOOD
GROS VENTRE
PLAINS-CREE
PLAINS-OJIBWAY
SAULTEAUX
MUSKEKOWUG
EASTERN CREE
MONTAGNAIS
BEOTHUK
CHINOOK
YAKIMA
WASCO
KLIKITAT
CAYUSE
UMATILLA
WISHRAM
NEZ PERCE
FLATHEAD
TILLAMOOK
MOLALA
ALSEA
KALAPOOIA
KUSA
YONKALLA
UMPQUA
TAKELMA
KLAMATH
TOLOWA
KAROK
YUROK
MODOC
BANNOCK
CROW
CHEYENNE
ARIKARA
HIDATSA
MANDAN
OJIBWAY
SANTEE-DAKOTA
MENOMINI
HURON
OTTAWA
NIPISSING
MISSISAUGA
ALGONKIN
ABNAKI
PASSAMAQUODDY
PENOBSCOT
MICMAC
PENNACOOK
MASSACHUSETTS

PLATE LXXXVIII

PLATE LXXXVIII

PRE-COLUMBIAN PATHOLOGY OF NORTH AMERICA

The left tibia of a male North American, pre-Columbian, Indian from Pueblo, San Cristobal, New Mexico, showing hypertrophy due to osteomyelitis or syphilis(?) or some general osteitis. This bone is figured to show type of hypertrophy which is commonly ascribed to pre-Columbian Syphilis. Original No. 99/6703, American Museum of Natural History.

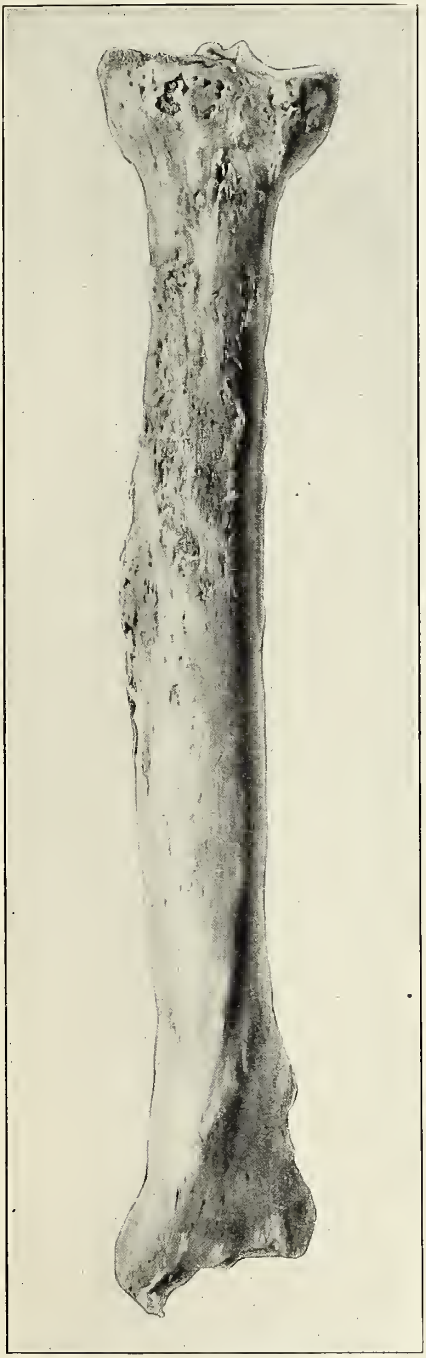


Plate LXXXVIII

PLATE LXXXIX

PLATE LXXXIX

PRE-COLUMBIAN PATHOLOGY OF NORTH AMERICA

a. Hypertrophied ulna of a pre-Columbian Indian from Pueblo, San Cristobal, N. M., showing a congestive osteitis which recalls the results of syphilis. Such evidence is, however, not sufficient to establish the presence of syphilis in pre-Columbian America. Original in the American Museum of Natural History.

b, c, d. Elbow-joint of a pre-Columbian Indian from Pueblo Bonito, N. M., showing the result of hypertrophic arthritis, with many eburnated surfaces. The exostoses are of highly cancellous bone. Original in American Museum of Natural History.

Plate LXXXIX

PLATE XC

PLATE XC

PRE-COLUMBIAN PATHOLOGY OF NORTH AMERICA

Humerus of a male pre-Columbian Indian of North America from May's Lick, Kentucky, showing, in anterior and posterior views, the hypertrophic changes which have deformed the shaft. Original No. 20/1268, American Museum of Natural History.

Plate XC

PLATE XCI

PLATE XCI

PRE-COLUMBIAN PATHOLOGY OF NORTH AMERICA

Upper figure. Diseased (tuberculous?) lumbar vertebrae of an early (pre-Columbian?) North American Indian from a mound in northern Louisiana, suggesting Pott's disease. (After Hrdlička.)

Lower left. Hunchback clay images, commonly found in the mounds of Arkansas, Missouri, and Tennessee stone graves. While suggesting Pott's disease it is doubtful whether the presence of them in the graves indicates any great prevalence of vertebral tuberculosis in those regions. Original in Peabody Museum of Harvard University.

Lower right. Photomicrograph of diseased bone taken from the specimen shown in Plate XCVI. X 100.

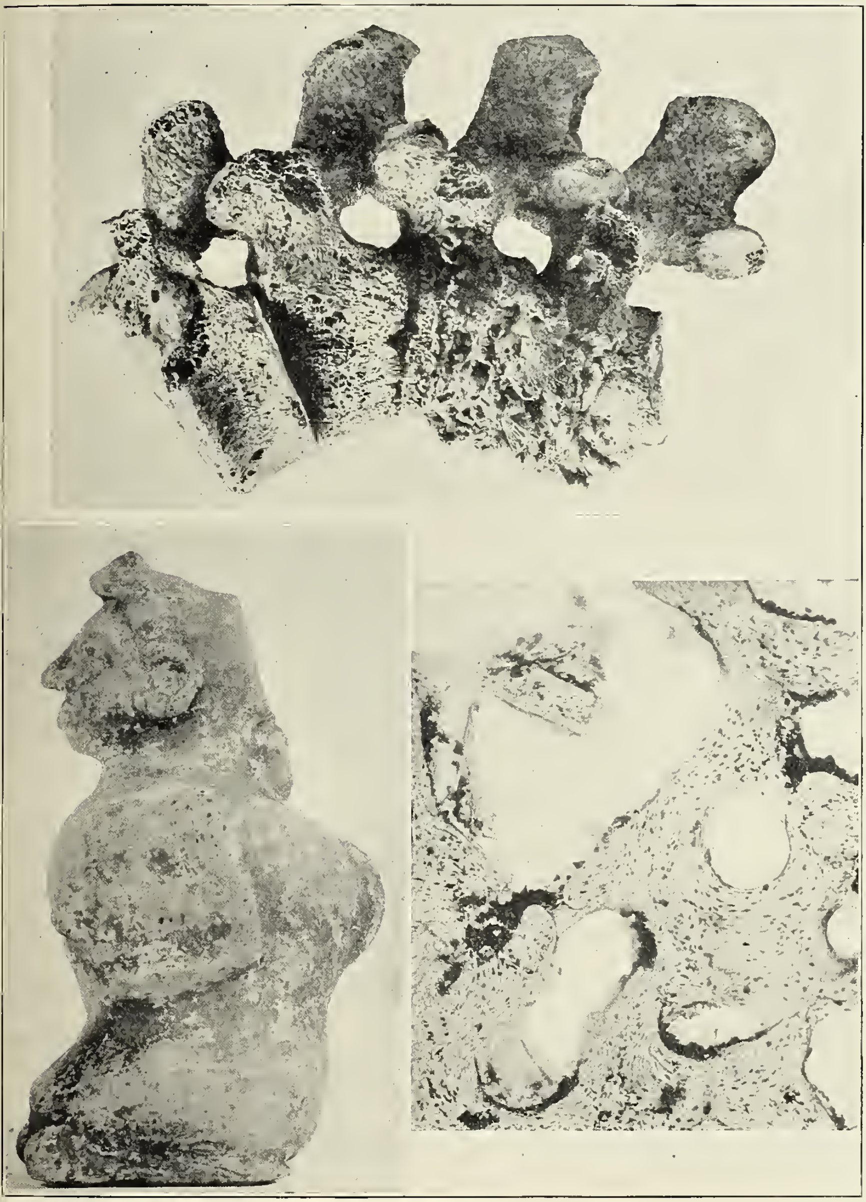


Plate XCI

PLATE XCII

PLATE XCII

PRE-COLUMBIAN PATHOLOGY OF NORTH AMERICA

a. and *c.* Posterior and lateral views of the lower end of a male humerus, pre-Columbian Indian of Grand Gulch, Utah, showing lesions of arthritis deformans. Original in American Museum of Natural History.

b. Diseased head of humerus of a pre-Columbian Indian, possibly due to a fracture of the neck and accompanied by arthritis deformans.

d. Lumbar vertebra of an Indian (pre-Columbian?) showing a type of ancient injury. The spear-point of antler has penetrated the canal of the vertebra and has remained fixed after possibly hundreds of years since the injury was inflicted. Death doubtless ensued shortly after the injury for there is no indication of healing. (After Miller.)

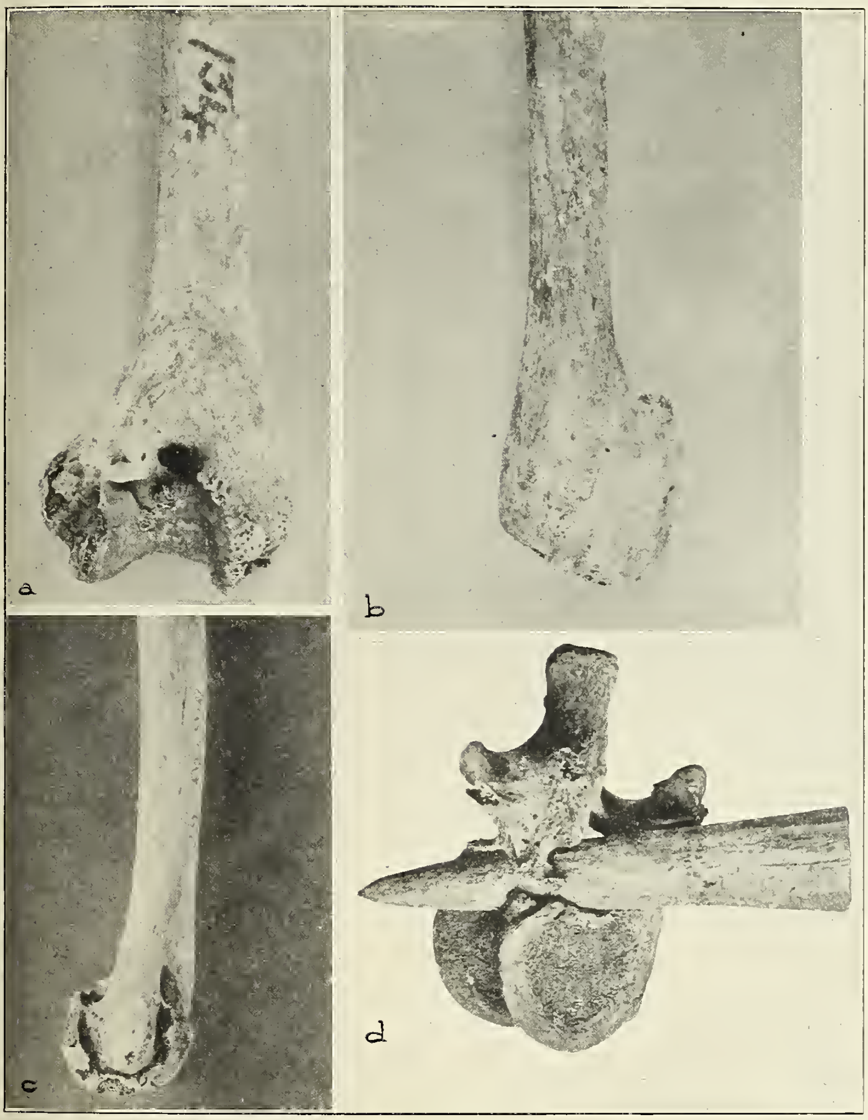


Plate XCII

PLATE XCIII

PLATE XCIII

PRE-COLUMBIAN PATHOLOGY OF NORTH AMERICA

Left. Photograph of the tibia shown in the drawing (Plate LXXXVIII). Male pre-Columbian Indian from Pueblo, San Cristobal, New Mexico, showing hypertrophic osteitis suggesting syphilis. Original No. 99/6703, American Museum of Natural History.

Right. Male pre-Columbian Indian vertebrae with osseous bridges forming an unusual type of vertebral arthritis. Grand Gulch, Utah. Originals in the American Museum of Natural History.

Plate XCIII

PLATE XCIV

PLATE XCIV

PRE-COLUMBIAN PATHOLOGY OF NORTH AMERICA

Posterior radiographs of the following bones:

a. Fractured and well-healed tibia, male pre-Columbian Indian, May's Lick, Kentucky, No. 20/1268, American Museum of Natural History.

b. Hypertrophied ulna (syphilitic?) of a male pre-Columbian Indian from Pueblo, San Cristobal, New Mexico. No. 99/6702, American Museum of Natural History.

c. Hypertrophied tibia (shown in Plate LXXXVIII) of a male pre-Columbian Indian of Pueblo, San Cristobal, New Mexico. No. 99/6703, American Museum of Natural History.

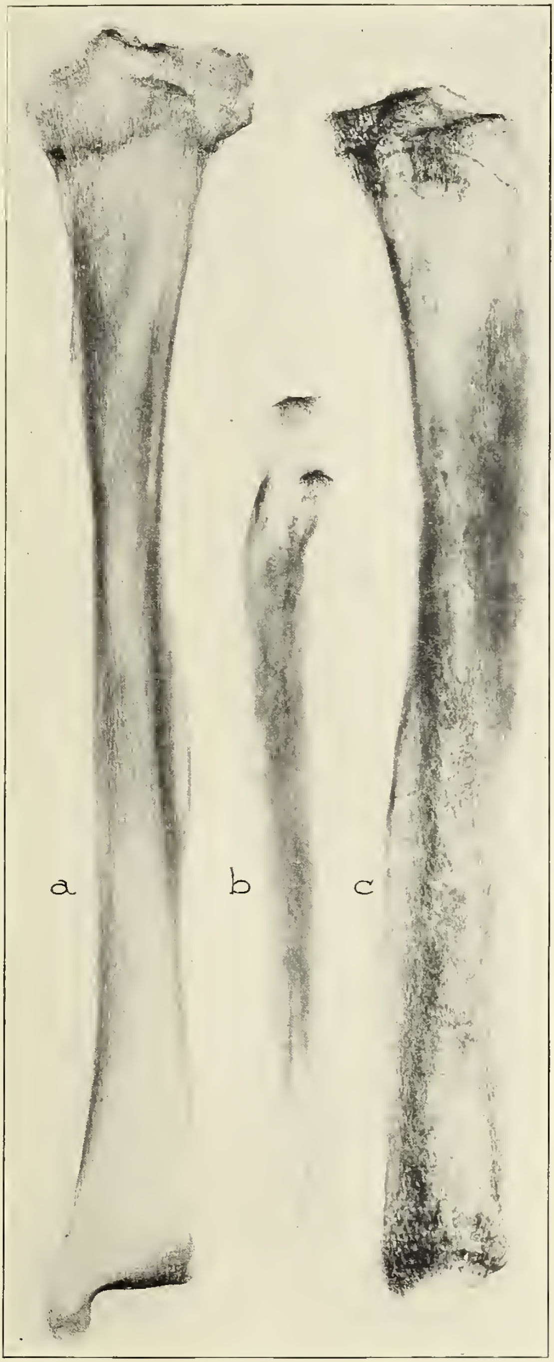


PLATE XCIV

PLATE XCV

PLATE XCV

PRE-COLUMBIAN PATHOLOGY OF NORTH AMERICA

Radiographs from the anterior surfaces of the same bones shown in Plate XCIV.

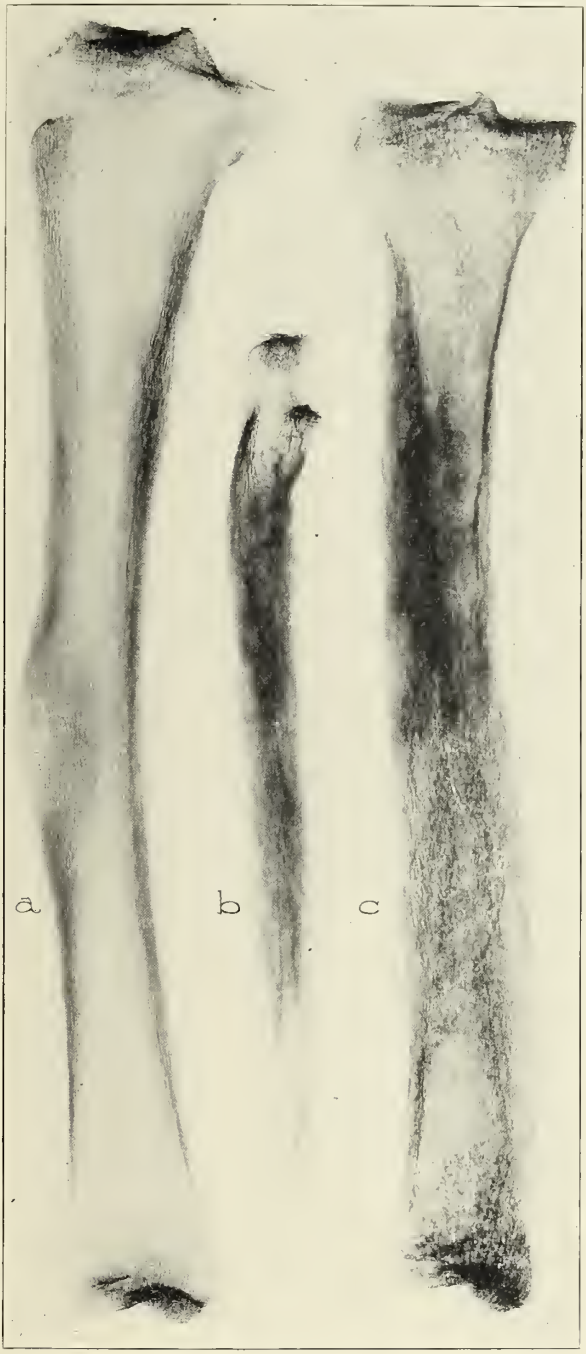


Plate XCV

PLATE XCVI

PLATE XCVI

PRE-COLUMBIAN PATHOLOGY OF NORTH AMERICA

Diseased lumbar vertebrae of a North American Pre-Columbian Indian. Male. Found at Grand Gulch, Utah. The original is in the American Museum of Natural History.

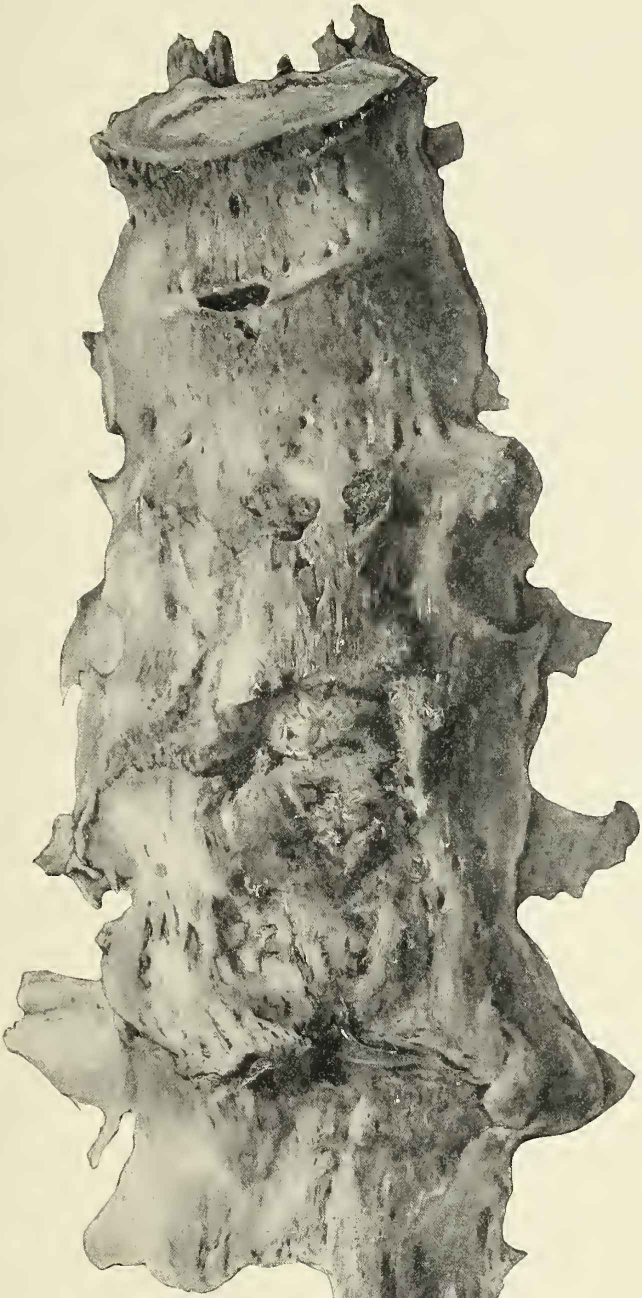


Plate XCVI

PLATE XCVII

PLATE XCVII

PRE-COLUMBIAN PATHOLOGY OF NORTH AMERICA

a. Exostoses of spondylitis deformans on sacrum, immediately below last lumbar of a male pre-Columbian Indian from Grand Gulch, Utah. Original in American Museum of Natural History.

b. Lower posterior surface of the right femur of a male pre-Columbian Indian from Cora, Mexico, showing lesions of osteo-arthritis. Original in American Museum of Natural History.

c. Spear-point injury in an ancient North American Indian.

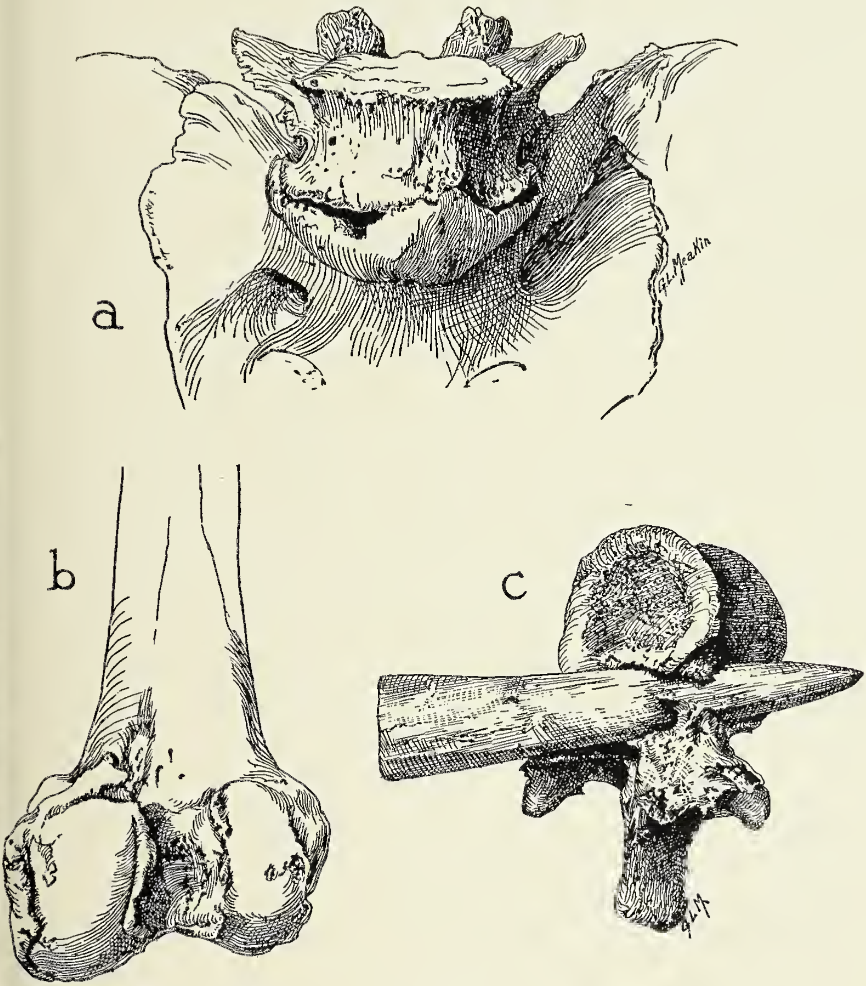


PLATE XCVII

CHAPTER XV

DISEASES OF THE ANCIENT PERUVIANS

Uta, as depicted on ancient water jars. Trephining in South America. Diseases of the teeth. Descriptions of Figures 46-49 and Plates XCV-CXVII illustrating Chapter XV. Figures 46–49 and Plates XCVIII–CXVII.

The paleopathology of South America is largely confined to the Peruvian region[1] and chiefly to that occupied by the Peruvian Indians under the Incas. This area embraced at times wide portions of what are now the modern states of Chili, Bolivia, Peru, Brazil and Ecuador, since at various times in the history of the Inca princes they sent conquering expeditions into these regions, on which they left more or less impress of their culture.

Of the peoples of the northwestern coast of South America, once ruled by a more or less mythical prince known as the Grand Chimu, and subsequently subdued by the Incas several decades prior to the coming of the Spaniards, little or nothing is known, save what we may learn from the ruins of their edifices, and the ornaments, textiles, potteries (huacos) and other objects taken from their tombs (chulpas). Nothing of the physical anthropology or paleopathology of this race is known.

The more ancient inhabitants of the Peruvian territory, the megalithic predecessors to the Incas, centered around Lake Titicaca. Later the Inca prince, Manco Capac, led the people northward to the place where his magic golden wand disappeared into the earth, and where he established the City of the Sun, the golden city of Cuzco, which still survives under the original name but is modernized by being the terminal of the Peruvian Railroad. Here, surrounded by high, rugged mountains and deep gorges they developed one of the most advanced American civilizations, which was only approached in perfection by the ancient Mayas of Yucatan before the subsidence of the earth, through geologic changes, resulted in unfitting their territory for human habitation.

[1] All that is known outside of this area is the pathological condition in the skull fragment of a primitive man, described by Ameghino as *Diprothomo platensis*, which shows a perforating skull injury, due possibly to an arrow point, which had been slightly septic but had been well healed.

On account of their well organized social systems, their agricultural and mechanic arts, military knowledge and architecture, their civilization has appealed to the imagination of students of history, sociology, and anthropology for many decades, centuries in fact. Since the discovery and first exploration and exploitation of Peru by the Pizarros and their companions from 1532-1540,[2] there have been many interesting and important contributions to our knowledge[3] of the anthropology, archeology and linguistics of the three or four larger "races" or groups of Indians who in ancient times inhabited the Peruvian territory (Figure 46) from the sea up to the highest mountain peaks, which at present reach an elevation of more than 18,000 feet.[4] These groups of peoples, variously known as the Aymara and the Quechua, in the central and southern highlands; the Huancas, in the north; and the Fungas or Chinchas, along the coast, besides a considerable number of unclassified tribes in the northeastern and northern regions of the Peruvian territory, all spoke a number of different languages, and differed from each other in many respects. Markham[5] finds a strong similarity running through the various languages and attributes them all to a common stem language, the Quichua or Runa-simi, of which there is a dictionary by Torres Rubio, which has been revised by Sir Clements Markham.

So little is known of the physical anthropology of these ancient

[2] The best modern account of this Spanish expedition is that of Wm. H. Prescott: Conquest of Peru. He based his account on the writings of the Spaniards to whom he gives abundant references.

[3] Chief among these is the work of E. George Squier: Peru, Incidents of Travel and Exploration in the Land of the Incas, London, 1877. This work was the result of several months personal exploration of the ancient civilizations of Peru. A very charming work is that of Sir Clements Markham: The Incas of Peru, London, 1912. Garcilasso de la Vega, a descendant of the Inca princes through the marriage of his Spanish father to an Inca princess has left very valuable records of the life of these people which have now almost entirely disappeared.

[4] Sir Clements Markham: Incas of Peru, London, 1912, p. 38, adduces evidence to show that there has been considerable elevation of the region since its occupation by the Spaniards, and was hence much lower at the time of the Incas. This would, if true, explain the possibility of raising maize around Lake Titicaca and Cuzco in ancient times in sufficient quantity to support a large population. There is little geological evidence to support such an extensive uplift as Sir Markham suggest, and if the region has risen at all it is only to be measured in feet. The conclusions of Darwin, quoted by Markham, are rendered doubtful by more recent evidence. It should be noted, however, that Dr. Edward W. Berry, on paleobotanical evidence has postulated a rise of two and a half miles in the Bolivian plateau since Pliocene times. Whether this uplift is at present continuous is not known, and we cannot be sure what part of it has taken place in the past 400 years.

[5] Incas of Peru: London, 1912. Chap. X, Language and Literature of the Incas.

peoples that no definite classification of them has yet been made.[6] The temples and huge walls built by the magalithic predecessors of the Inca race, as well as the structures reared under the direction of the Incas, have appealed strongly to the early explorers, many of whom spent huge sums in investigating the monuments in search of treasures of gold and silver. They destroyed much more than they recovered, although occasionally large amounts of precious metals were obtained. Squier tells very clearly how objects of interest to the scientific man were ruthlessly destroyed. Skeletons and mummies were thrown to one side as so much soil, and thus was lost through hundreds of years precious evidences bearing on the anthropology and paleopathology of these races. The same statement holds true, however, for even scientific explorers in the Orient, where the chief interests were archeological and human remains have been largely disregarded. Well organized exploring expeditions of a scientific nature, such as those from the Smithsonian Institution, and the Yale University and National Geographic Society Peruvian Expedition headed by Professor Hiram Bingham have been well described[7] and will be referred to in this chapter. The enormous size of the buildings, the huge blocks of stone, beautifully fitted, of which they are composed, as well as the enormous distances they must have been transported, without vehicles of any kind, have aroused the amazement and wonder of students of the subject and have so far largely over-powered other interests.

The antiquity of the ancient Peruvian race is not known, but the megalithic buildings, the probable authenticity of the long list of Inca kings,[8] and traditions carry some indication of an antiquity of three thousand years (from 1300 B. C.), although there is little definitely known of these ancient races prior to the thirteenth century A. D.[9]

There is sufficient evidence to prove the presence of a number of interesting diseases among these ancient peoples, who with the Nahua, the Maya, the Chibcha, the Toltecs and the Aztecs, represented the highest development of American civilization, prior to its destruction by the Spaniards in the sixteenth century. The study of these ancient races forms one of the most interesting phases of ancient history.

[6] Aleš Hrdlička: Some Results of recent anthropological Explorations in Peru. Smithson. Misc. Collect., Wash., 1911, lvi, 2.

[7] Hiram Bingham: In the Wonderland of Peru, Natl. Geog. Mag., Wash., xxiv, 1913, 387–573, 250 photos; The Story of Machu Picchu, Ibid., xxvii, 1915, 172–217, as well as the memoir of Eaton which is referred to below.

[8] Sir Clements Markham: Incas of Peru, 1912, Chap. III.

[9] Clark Wissler: The American Indian, New York, 1917, 271.

Breasted has called the attention of the Orientalists, particularly, to the methods pursued by the Americanists in elucidating the history of the early American people. But even the Americanists have not been making use of all available data, and until we know all that is to be known from all evidences we do not know early American civilizations as they should be known.

On the whole the well-being of the ancient Peruvians seems to have been a very healthy one, and only a few diseases are known. Létulle has noticed, in an ancient Peruvian skull, probably pre-Columbian, a condition similar to goundou or gundu, (Figure 47) a disease met with in West Africa, and characterized by a swelling of the bone at the root of the nose. The disease is also known to occur in Malaysia.[10]

The features depicted on an ancient Peruvian water jar (Figure b Plate CXII) indicate the prevalence of gundu in pre-Columbian times and recall the usual form (Figure 47) taken by the disease in Africa.[11] This water jar, about 8 inches high, preserved in the American Museum of Natural History, must have been modeled by some early potter who was familiar with the lesions of goundou. The disease is not known to occur in Peru at the present day.

Among the most loathsome of the present day dermatological lesions found in Peru at the present time is the disease known as *Verruga peruviana.* The history of this disease and its etiology are given by Strong[12] from whose report it appears that this disease has afflicted the inhabitants from remote historical times. The disease appears first as a fever, with anemia and a nodular eruption upon the skin. Over four centuries ago, during the reign of the Inca, Huayan Capac, thousands of lives were swept away, supposedly by this disease. Zarate[13] in his history of the conquest of Peru says that Verruga was more destructive than small-pox. De la Vega, a Peruvian writer of mixed Inca and Spanish blood, says that a quarter of the invading army of Francisco Pizarro perished from this disease. The presence of this disease in pre-Columbian times is authenticated by the preservation of an ancient vase or water jar described by Ashmead.[14] This pottery

[10] Schlagenhaufen: 1918. Schädel eines an Gundu erkrankten Melaniesiers. Mittheil. Geog. Ethnol. Ges., Zurich, with a good bibliography of the disease.

Joseph Gaston, 1913. Le Goundou. Bull. Soc. d'Anthrop. de Paris, 65, IV, No. 3–4, p. 389.

[11] A. Castellani: Manual of Tropical Medicine, 1913, 1345.

[12] Harvard School of Tropical Medicine. Expedition to South America, 1913.8.

[13] Zarate: Historia del discubrimento de Peru, 1545, i, 4, ii, 1.

[14] Albert S. Ashmead: 1895. Photographs of two ancient Peruvian vases, with some particularities presented by them, and some observations about them. J. Cutan. & Genito-Urinary Diseases. xiii, 465–466.

figure, evidently of an achondroplastic dwarf, represents a human figure whose entire body is covered with nodular eruptions in the skin. It may very well represent the Verruga peruviana (Plate CXII, a).

UTA, AS DEPICTED ON ANCIENT WATER JARS

One of the most dreaded and most widely distributed diseases afflicting the inhabitants of Peru and adjoining territory at the present time is *Uta*, an ulcerative disease which has been known in Peru since prehistoric times. Lesions of the malady are frequently depicted on the "huacos" or ancient pottery (Plate CXI) of the Incas. The disease has been widely misunderstood and has been confused with other ulcerative processes and has been regarded as a prehistoric form of syphilis and leprosy. More recently it has been regarded as a form of lupus vulgaris, or as a distinct infection. Its etiology was utterly unknown prior to the Harvard expedition to South America, when it was finally diagnosed as uta or Leishmaniasis,[15] due to an undetermined species of *Leishmania*. They were able to obtain the flagellate stage of the organism in cultures and to inoculate successfully a dog with it. Uta or Leishmaniasis is widely distributed today, being known from Argentine northward to Mexico.[16] That it probably existed for many centuries in pre-Columbian times is indicated by the features depicted on the "huacos" or Inca pottery figured by Tamayo[17] and De Palma,[18] examples of which are not uncommon in museum collections. Several examples are shown herewith (Plates CX, CXI and CXII) by courtesy of the American Museum of Natural History. Since the disease attacks only the skin, flesh and cartilage, and does not affect the bones nothing has been seen on the various skeletal elements in the collections, to indicate its presence (Plate CII, a and c).

The disease must have been very prevalent in ancient times if we may judge by the frequency of its representation on the ancient potteries. The lesions depicted on the jars are those usually of the most advanced stages. The disease begins with a small, insignificant-appearing papule which gradually increases in size, and after a month or two a lesion measuring usually from 1 to 3 cm. in diameter is formed. The face, mouth, lips, ear and neck are more commonly affected, but

[15] Richard P. Strong: Harvard School of Tropical Medicine. Expedition to South America. 1913, Chap. vi.

[16] Edmundo Escomel: Leishmaniasis, Buenos Aires, 1917.

[17] M. O. Tamayo: La Uta en el Peru, Lima, 1908.

[18] Ricardo de Palma: La Uta del Peru, Lima, 1908.

the ulcerations may occur on the arms or legs, being especially common in children. Some of the features depicted on the water jars evidently represent the effects of surgical interference to prevent the spread of the disease. Such a condition is thus evidently pictured in the vase shown in fig. a Plate CX. It is not remarkable, particularly, that the ancient Peruvians should have depicted the lesions of this loathsome disease on their water jars since the most astonishing work of these early Indians was their modelling and painting in clay, and it is not too much to say that not only the fauna and flora, but also the manners and customs of the people, are depicted or modelled on their vases. These "huacos" have been collected and studied from early times and Ashmead especially has called attention to the pictures of pathology which some of them carry.

There is only one other type of skin lesion depicted on the "huacos" and this is shown in Figure c Plate CXII, where the seated figures are shown examining the soles of their feet, in which there are numerous rounded openings from which have been removed the egg-sacs of the "nigua" a kind of sand flea or jigger abundant in certain parts of Peru which bore holes in the soles of the feet and deposit their egg sacs. Unless these sacs are removed entirely disastrous results are likely to ensue.

TREPHINING IN SOUTH AMERICA

The antiquity of the surgical procedure of trephining or trepanning has already been discussed (Chap. XII) and it remains to be told here to what a high degree of frequency it was performed, especially in Peru, some of the probable causes of this operation, and the basis on which the conclusions rest. In Peru trephining reached a high degree of perfection, being extensively practiced.

Bandelier (1904) found that trephining is still performed in Bolivia, and probably also in the highlands of Peru by the Aymara Indians. The operation, as witnessed by Bandelier was performed with well-sharpened pocket knives, by the *shaman*, who is also frequently a medicine man.[19] The process was usually performed for depressed fractures, for headaches and as performed in Bolivia was essentially one of cutting and scraping. Some of the specimens collected by Bandelier, now preserved in the American Museum of Natural History, indicate that the process was repeated from two to four times, without fatal results (Plate CVIII and CIX).

[19] Clark Wissler: The American Indian, N. Y. 1917, 187.

A skull, probably trephined post-mortem, was discovered at Chaclacayo, near Lima, Peru, and described by Otis Mason,[20] although it is easily possible that the operation may have been fatal, since there are other skulls, such as the one described by Escomel[21] which shows that after two successful operations the third was fatal, although the third may also have been post-mortem. Many of the operations seen in the Muniz collection[22] were performed during life, with many of the skulls showing good recovery and partially healed wounds, but the percentage of pre- and post-mortem operations in Peru has not been determined. The cause for the operation as outlined by Tello of Lima[23] are: a) an antecedent fracture; b) a simple traumatism of the cranium which denuded the periosteum was followed or not by an inflammatory process; c) a circumcised periostitis or osteoperiostitis, perhaps also of traumatic origin; d) lesions possibly of a syphilitic nature. Some doubt has been expressed as to the age of the specimens described by Tello, and especially is the nature of pre-Columbian syphilis in doubt.

The contribution of Peruvian trephining which surpasses all others is that of Muniz and McGee[24] based on an extensive collection of skulls and skeletons and other anthropological material, made by Muniz during the course of several years exploration. Since this splendid memoir is so readily accessible to students of the subject, it will not be reviewed here. The report contains a careful, systematic description of ancient trephined skulls.

In a previous paper[25] I have described the practice of trephining so that little need be said here as to the method of operation. I have thought it worth while to add, however, a description of two skulls and illustrate them to show on the one hand a detailed figure of the result of trephining by scraping (Fig. b Plate CVII), and on the other the cause of trephining in a skull with a linear fracture (Fig. b, Plate CX).

[20] Otis T. Mason: 1885, The Chaclacayo trephined skull; with measurements by Dr. Irwin C. Rosse, U. S. A. Proc. U. S. Nat. Mus., Wash., 410–412, pl. 22, and list of measurements.

[21] Edmundo Escomel: Un caso interesante de trepanacion incaica. La Cronica Medica, Lima, 1916, with fig. Also: Un cas de trepanation prehistorique. Bull. et mém. Soc. de Chirur. Par., Mars, 1909.

[22] W. J. McGee: Primitive trephining, illustrated by the Muniz peruvian collection. Johns Hopks. Hosp. Bull., v, 1–3, 1894.

[23] Julio C. Tello: Prehistoric Trephining among the Yauyos of Peru. Proc. 18th Intern. Congress Americanists, London, 1913, 75–84, 3 pls.

[24] M. A. Muniz and W. J. McGee: Primitive Trephining in Peru, 16th Ann. Rep. Bur. Amer. Ethnol., Washington, 1897, 40 plates.

[25] Studies in Paleopathology: Some ancient Skull Lesions and the Practice of Trephining in prehistoric Times. Surgical Clinics of Chicago, June, 1919.

In the study above referred to I mentioned skulls which showed certain variable necrotic areas, none of which are ever trephined. I am able, through the kindness of Doctor George F. Eaton of Yale University to show a radiograph (Plate XCIX) of such an ancient Peruvian skull. What the lesion is due to is uncertain, but it is fairly common.

DISEASES OF THE TEETH

Little is known of the diseases of the teeth of the ancient Peruvians, since there have been few studies made on them. Dental practices were probably not developed among these early peoples, although certain dental procedures, though not for therapeutic purposes, have been described by Van Rippen,[26] basing his deduction on the collections at Harvard University. He established the fact that the Maya people of Central America and the primitive races of Ecuador were the first to prepare cavities in living teeth and insert inlays made to fit the cavities, without having any prophylactic measures in view. It was probably an attempt to beautify the semi-savage countenance. Thoma, also, studied a number of ancient Peruvian skeletons preserved in the Harvard collections, and was able to show the presence of dental disturbances, such as abscesses of the jaws, cleft palate and hare lip.

The presence of syphilis among any of the pre-Columbian races of the Western Hemisphere is one of the unsettled questions in the paleopathology of the early human races and I want to present here a few of the evidences on which the statements that it *was* present, and there are many scientific men who do think so, have been based. Doctor George F. Eaton[27] who accompanied the Yale University Expedition to Peru to excavate the lost city of Machu Picchu has described the skull of a child, seven years of age (Fig. b, Plate CII), showing on the frontal bone a deep penetrating sinus which perforated the inner table of the skull and the child doubtless perished from an infection (syphilitic?) of the meninges. It seems to me, however, that there is no reason why syphilis is involved in the question of this skull,[27a] since the sinus may well have developed from a traumatism, resulting in a condition similar to that seen in chronic traumatic osteomyelitis.

[26] B. Van Rippen: Pre-Columbian Operative Dentistry of the Indians of Middle and South America. Dental Cosmos, Sept. 1917, 1–15, 17 figs.

[27] The Collection of Osteological Material from Machu Picchu. Memoirs of the Connecticut Academy of Sciences. V, pl. xxiii, fig. 1–2, 1916.

[27a] Thulié, M., 1877. Sur la déformation syphilitique du crâne. Bull. de la Soc. d'Anthrop de Paris, 2nd ser., xii, 459–460.

A saber-blade deformation of the tibia has often been said to be due to syphilis and I figure here (Plate C) an ancient Peruvian tibia showing this deformity. But unless the one who makes the diagnosis is capable of distinguishing between a pathological and a morphological condition his conclusions are of little value. Platycnemia is a well established fact in anthropology and is of considerable importance and this has often been confused by medical men, ignorant of anthropology, with a pathological condition. A flattened tibia is not at all significant of syphilis, by itself. Unless accompanied by other phenomena it is useless as a diagnosis. Hutchinson's teeth, once thought to be positively diagnostic of congenital syphilis, we now know to be a result of malnutrition. The tubercle of Carabelli[28] has often been cited as a true diagnostic character of congenital syphilis and I have shown that this character is an inheritance from man's fossil forebears. A variety of phenomena then have been regarded as syphilitic in nature, so that one is tempted to say that when one meets an unknown condition it seems easiest to say: "Why, that's syphilitic," which it may or may not be, and probably the latter.

The presence of an intense catarrhal condition of the sinuses of the face, *pansinusitis*, is indicated by a skull (Fig. d, Plate CII), preserved in the American Museum of Natural History, which shows in the forehead an enormous fistula from which there had been for years a chronic suppuration. Through this fistula one may run a probe into nearly all the Sinus paranasals and it certainly was an intense infection. The fistula is lipped as if an operculum of some substance had fitted into it, and the frontal bones and nasal bridge are greatly roughened.

In the collections at Yale University there is a skeleton which is extremely light and fragile. The bones are of a pale yellow color and the walls of the bones are so extremely thin that one can run a pin into the leg bones. Without a more detailed study of this specimen it would, of course, be hasty to conclude as to its nature, but it suggests a nutritional disturbance similar to that seen in osteomalacia. Other nutritional disturbances are seen in the porosities of the skulls (Plates CXV and CXVI), frequently in children. Often these osteoporosities are paired, in the roof of the orbit, on the frontal, parietal and elsewhere.

Occasional osteomata are met with (Plate XCVIII), occurring usually on the frontal, always single, never very large, and always

[28] The Tubercle of Carabelli and Congenital Syphilis. Annals of Medical History, I, no. 4, 1919.

smooth, dense ivory-like bodies exactly like the cranial osteomata seen today.

The surgical implements employed by the ancient Peruvian surgeon are shown herewith (Plate CVI). How these instruments were cleaned is uncertain. They may have wiped them on their dirty, greasy, blankets between operations, or they may have been rather cleanly. Judging by their descendants they were not. They knew something of antiseptic substances as shown by the materials wrapped with bodies, but how they employed these in surgery is not known. Their surgical practices, other than those of trephining and amputation of the nose and lip, were confined to amputations such as that shown in Figure d, Plate CXII.—Other minor operations are suggested in Figure c, Plate CXII.

The influence of climate on the diseases of any race are clearly established by the work of recent times, but we do not yet know a great deal about climatic influences on ancient civilizations although Ellsworth Huntington[29] has made a great beginning on this subject.

The ancient Peruvians embalmed their dead, though they did not by any means carry their embalming methods to such a great degree of perfection as did the ancient Egyptians. There is no indication that the Peruvians withdrew any of the viscera. The body apparently was always wrapped and allowed to dry, a very convenient method and one to which the climate was especially adapted. The bodies were kept in chulpas or tombs, caves and other places and brought forth on feast days. When the vandals began destroying the ancient tombs in their mad search for gold, the mummies of course were thrown aside, and all we have left are the undiscovered burial places and what the gold hunters failed to destroy.

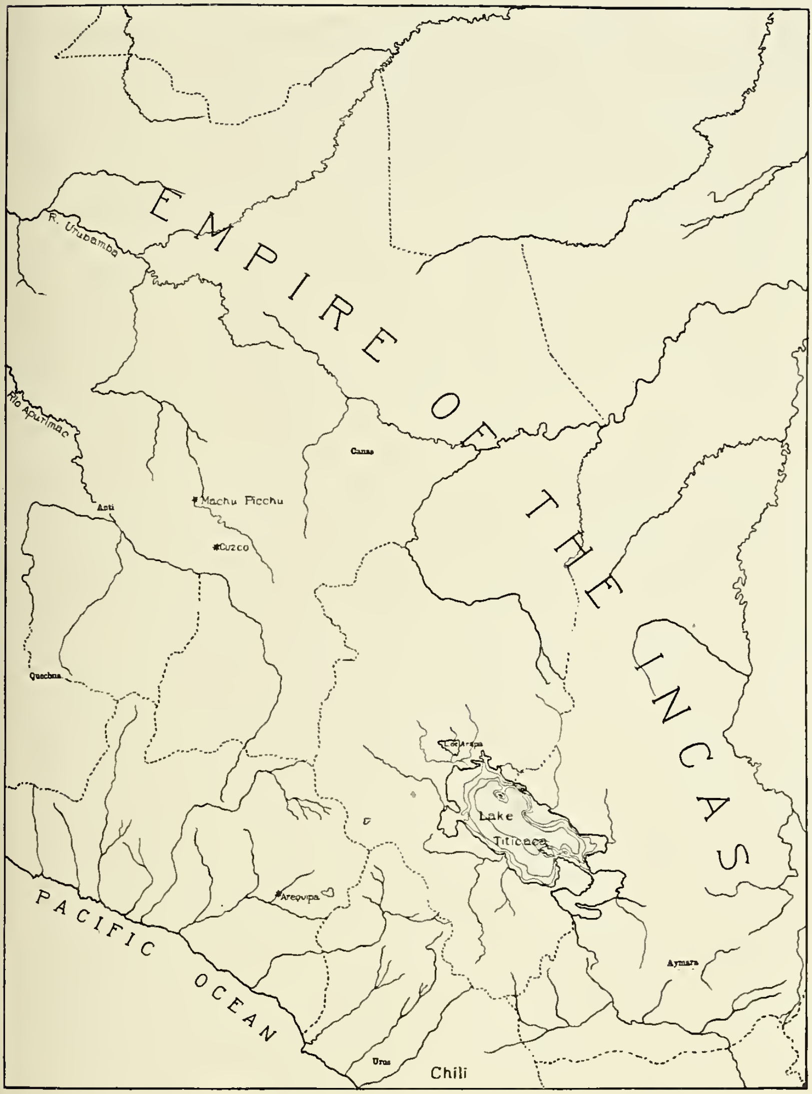
Since this is the first survey of the paleopathology of ancient Peru which has ever been made it would be hasty and unwise to attempt any general conclusions as to the source of the diseases indicated by the above described remains and of their influence on the civilization and life of the people. That the influence was at times great is evident since many of the above-mentioned diseases doubtless spread over the country at times in epidemic form. There are certain springs in the mountains from which the Indians warn the rash traveller since they say they are the source of *Verruga*. The unclean habits of the modern Indians of Peru may be some indication of the unsanitary conditions among which their predecessors lived.

[29] The Climatic Factor as illustrated in Arid America. Carnegie Institution of Washington. Publication 192, 1914. Civilization and Climate, New Haven, 1915.

DESCRIPTIONS OF FIGURES 46–49 AND PLATES XCVIII–CXVII ILLUSTRATING CHAPTER XV

FIGURE 46

Map of that portion of South America inhabited in ancient times by the peoples subject to the rule of the Inca princes. The region is all very mountainous. (From Sir Clements Markham.)



EMPIRE OF THE INCAS
R. Urubamba
Rio Apurimac
Canas
Anti
Machu Picchu
Cuzco
Quechua
Lake
Titicaca
Arequipa
Aymara
PACIFIC OCEAN
Uros
Chili

Figure 46

FIGURE 47

FIGURE 47

Face of a west African negro showing lesion of goundou, for comparison with the countenance depicted in the ancient Peruvian water jars (Plates CXI and CXII). (After Castellani.)

Figure 47

FIGURE 48

FIGURE 48

Map of the northern part of South America and the southern part of North America showing the distribution of Indian tribes, locations where important paleopathologic objects have been found and the distribution and relations of areas where trephining has taken place. Compare the distribution of trephining shown in Figure 29, Chapter XII.


Yuma
Papago
Opata
Yaqui
Tarahumare
Mayo
Lipan
Tepehuanes
Carrizo
Huichol
Nahua
Aztec
Zapotec
Maya
Arawak
Chocos
Yumana
Quito
Barbacoan
Esmeraldan
Quitus
Peban
Amazon River
Yuncan
Cholones
Lorenzan
Lima
Cashibos
Anti
Canas
Quechua
Cuzco
L. Titicaca
Arequipa
Aymara
Uros
Trephining

FIGURE 48

FIGURE 49

FIGURE 49

The pre-Columbian (possibly five hundred years old) female skull from Amazonas, Peru, showing a variant of the Sincipital T (shown in A). The cauterization must have been very intense, since great osseous ridges have developed along the lines of the incisions (shown in detail cross-section in B). The skull is the property of the American Museum of Natural History. Photographs of this skull are shown in Plate CIV and photomicrographs of pathologic bone in Plate CV.

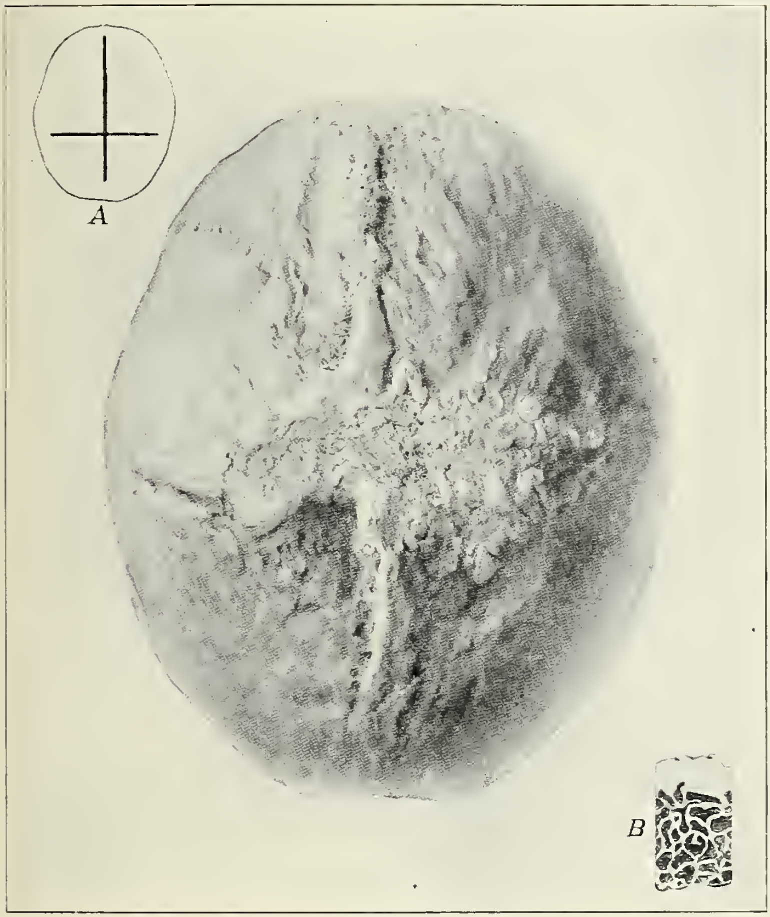


FIGURE 49

PLATE XCVIII

PLATE XCVIII

Left. Ancient Peruvian skull from Ancon showing temporal osteoma. Capacity of skull 1105 cc. No. 7214, Peabody Museum of Harvard University.

Right. Lateral view of pelvis of Peruvian showing effects of luxation of femur and formation of new acetabulum. No. 13448, Peabody Museum of Harvard University.

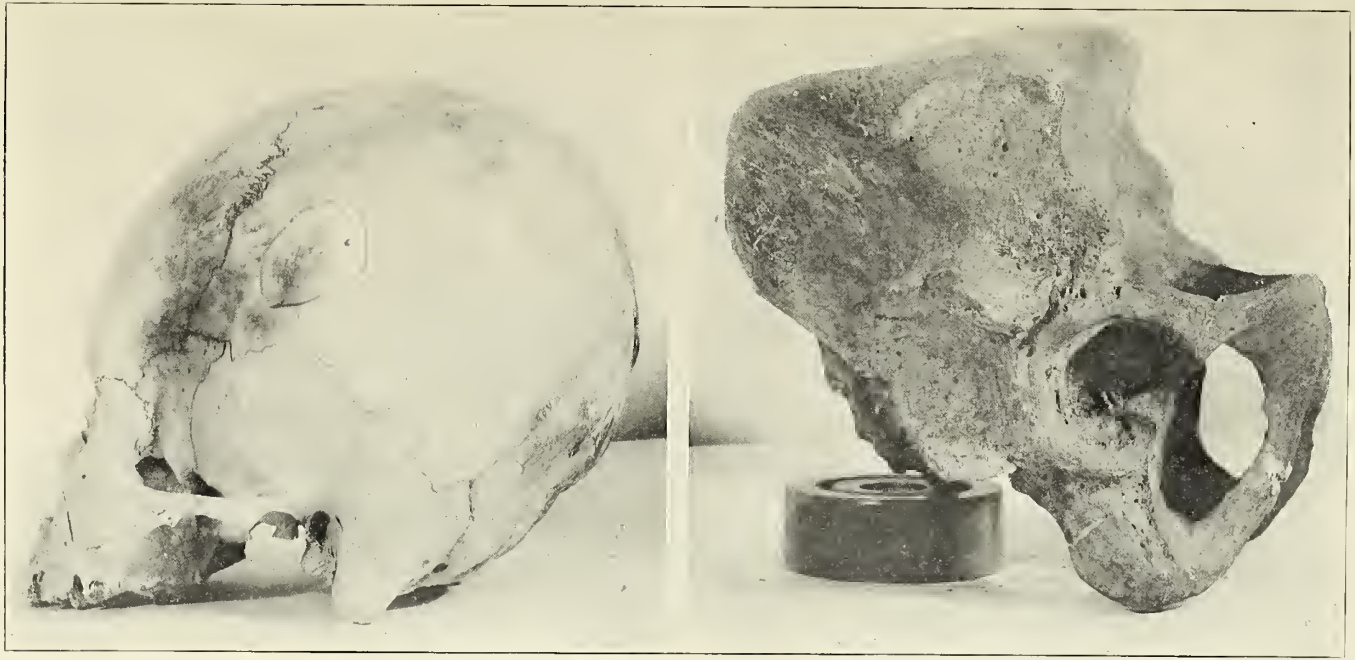


Plate XCVIII

PLATE XCIX

PLATE XCIX

Skiagram by Doctor Eaton of an adult female skull from a cave near Machu Picchu, Peru, showing a healed lesion in the right parietal eminence.

Plate XCIX

PLATE C

PLATE C

a and *b*. Normal right tibia of a young male Peruvian from a cave near Machu Picchu compared to a pathological (B) syphilitic? left tibia of same. After Eaton.

c and *d*. Skiagraphs of above described tibiae. After Eaton.

Plate C

PLATE CI

PLATE CI

1. Right femur of an adult, female, pre-Columbian Indian found in a cave of the Machu Picchu region, Peru. The bone appears free from disease and is published for comparison with the next femur. About 1400 A. D. (After Eaton.)

2. Left femur of the same skeleton, showing extensive syphilitic periostitis. The fracture was produced after the bone was found. (After Eaton.)

3, 4. Skiagrams of the right and left femora of the same skeleton, anteroposterior view. (After Eaton.)

Plate CI

PLATE CII

PLATE CII

a. Photograph of a patient in an advanced stage of the *uta* disease, for comparison with the features depicted in the ancient water jars. (After Tamayo.)

b. Skull of a child, seven years of age, from a cave near Machu Picchu, Peru, presenting necrosis (syphilitic) of the frontal bones, and an abnormal condition of the metopic suture. The black spot above the sinus is where the skull had been charred by fire and the opening on the coronal suture is a post mortem fracture. (After Eaton.)

c. Skull of an ancient Peruvian, the bones of which show the influence of uta around the nasal region. Indicated in the depressed nasal bones. (After Tello, who ascribes the lesions to syphilis.)

d. An ancient Peruvian skull collected by Bandelier at Chimbote, Peru, showing in the frontal fistula evidences of bilateral pansinusitis of long standing. The fistula opens directly into the nasal chamber, through the frontal sinuses. Below the fistula the surface of the bone is quite carious, possibly caused by the pus flowing out over a number of years. Original in the American Museum of Natural History. Courtesy of Mr. C. W. Mead.

PLATE CII

PLATE CIII

PLATE CIII

ANCIENT PERUVIAN PATHOLOGY

a. Skull of a young woman, about 17 years old, showing extreme Aymara or highland deformation. Lateral view. From a cave near Machu Picchu. (After Eaton.)

b. Basal view of an adult male (?) skull from a cave near Machu Picchu, Peru, showing partial fusion of the atlas and the occipital bone. (After Eaton.) This condition has been ascribed by some students to the effects of spondylitis deformans, but there are some grounds for believing it to be a morphological and not a pathological condition.

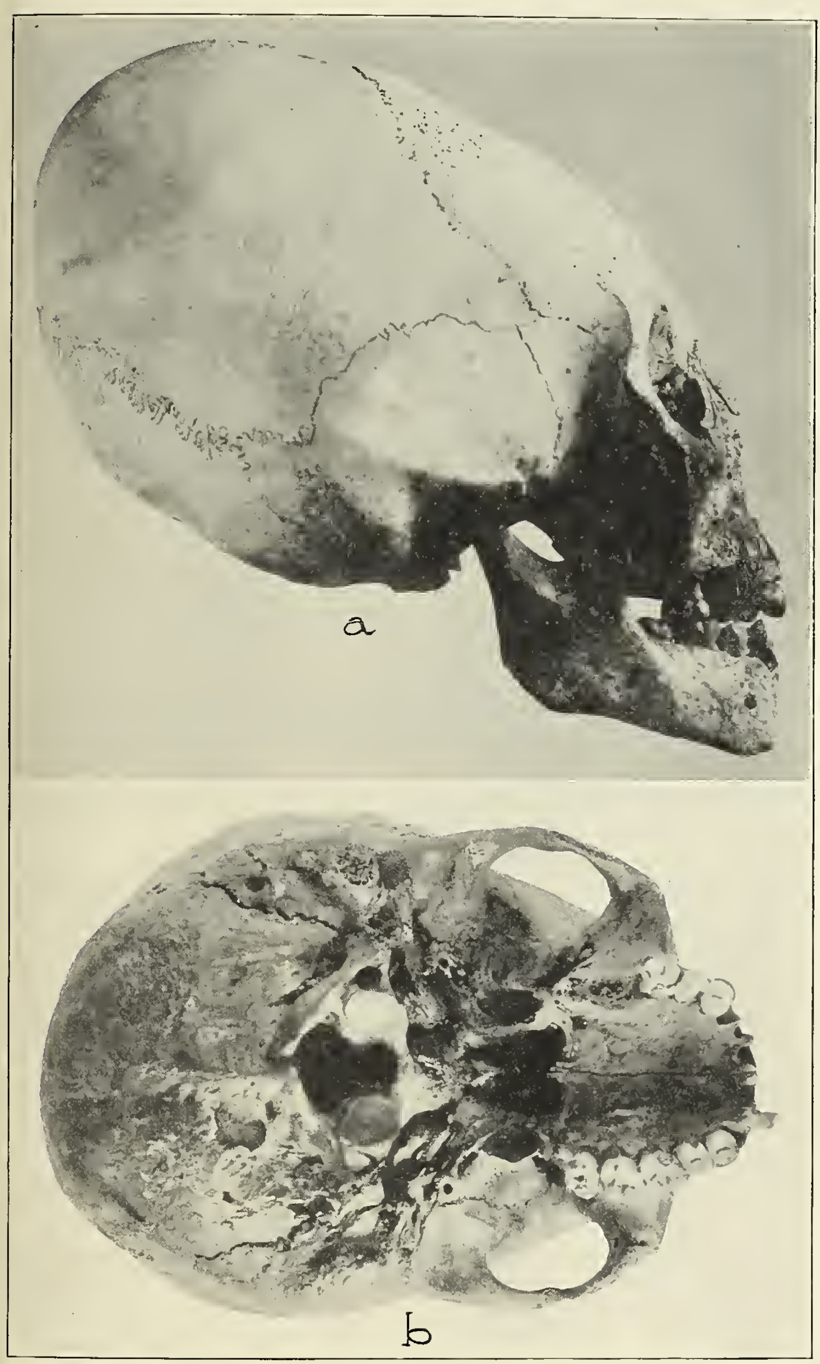


Plate CIII

PLATE CIV

PLATE CIV

ANCIENT PERUVIAN PATHOLOGY

A pre-Columbian female skull from Peru showing the effects of the cautery (see figure 49). Photomicrographs from this skull are shown in Plate CV. Original in American Museum of Natural History.

a. Lateral view.

b. Occipital view.

PLATE CIV

PLATE CV

PLATE CV

a. Photomicrograph of outer table of ancient Peruvian female skull shown in Plate CIV, indicating the dense aggregations of osseous lacunae. X 200.

b. The hypertrophied diploē of the parietal of same skull. X 200.

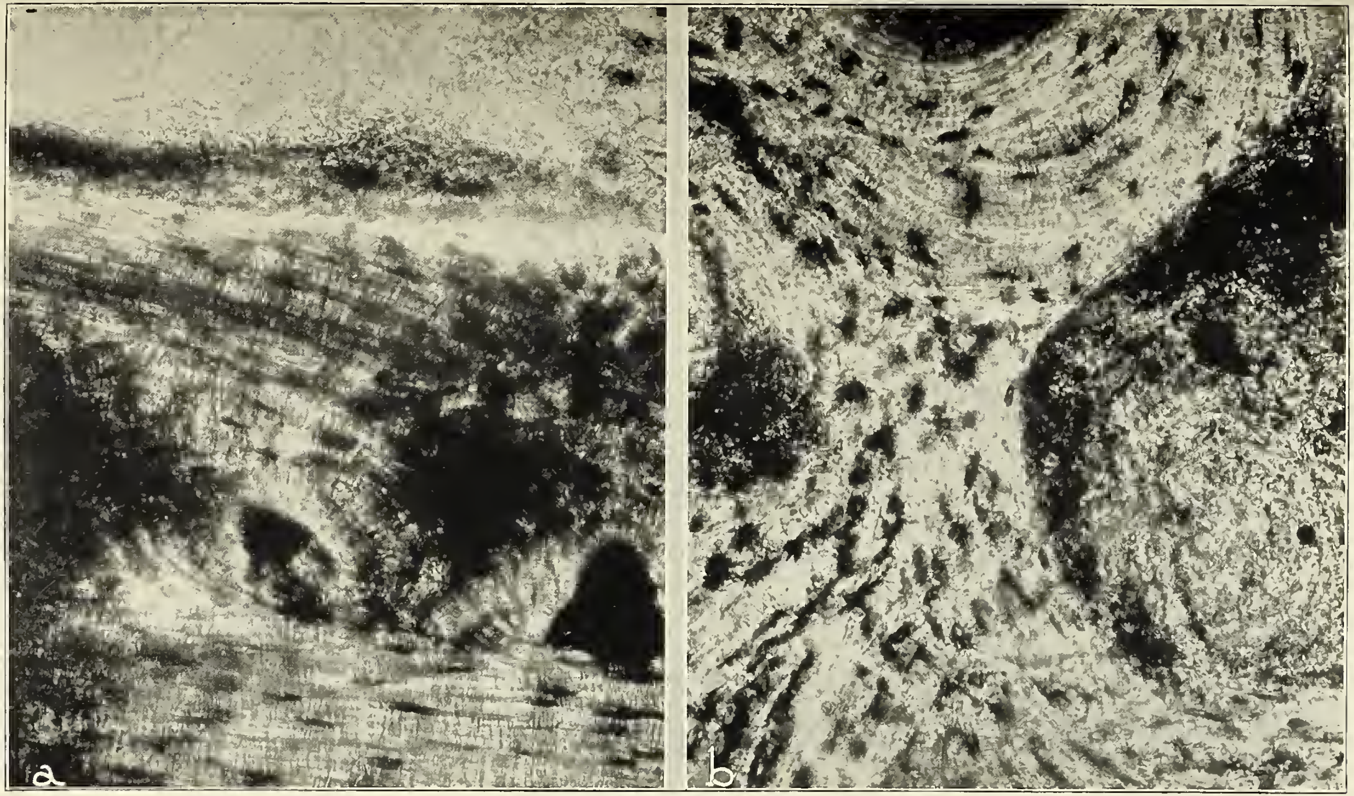


Plate CV

PLATE CVI

PLATE CVI

Primitive surgical instruments of obsidian and metal (copper or bronze), doubtless used by the prehistoric Peruvian surgeons in performing the operations of trephining, amputation and incisions of all kinds. The instruments are well adapted to the various procedures involved: cutting, sawing, scraping, and boring. Collected in the highlands of Peru, 150 miles from the coast by Aleš Hrdlička. a-b-c knife-like instruments which were doubtless quite effective and easily sterilized. d- a boring instrument, slightly injured. g-h bronze or copper instruments to which a haft of wood was fitted and tied with thongs. Originals in the United States National Museum. Photograph from the Smithsonian Institution.

PLATE CVI

PLATE CVII

PLATE CVII

ANCIENT PERUVIAN SURGERY

a. A reconstructed prehistoric surgical operation, shown also in the Frontispiece. Doubtless a scene like this ensued at the prehistoric trephinings.

b. Occipital view of a pre-Columbian skull from Peru showing a large trephine opening on the right lambdoid suture. A wide depressed area around the trephine opening indicates the area denuded by scraping. The wound had healed well as may be seen by a close examination of the photograph. This picture shows especially well the effects of trephining by the process of scraping. Collected in the highlands of Peru within 150 miles of the coast by Aleš Hrdlička. Original in the United States National Museum. Photograph from Smithsonian Institution.

Plate CVII

PLATE CVIII

PLATE CVIII

ANCIENT PERUVIAN PATHOLOGY

a. A very unusual ancient Peruvian skull showing five trephine openings, two of them incomplete or healed over after once being completed. Edmundo Escomel, of Arequipa, Peru, who described this skull and from whose photographs the drawing is made, says: "There are on this skull three series of trepanations in different stages of repair." It will be noted that the incompleted or healed openings show no evidences of a drilled margin, but they appear to have been done by cutting and scraping.

b. A scheme on a modern skull outlining the hypothetic placing of borings as devised by Lucas-Championniére.

c. The rondelle or plaque of bone removed.

d. The crenated margins removed by chiselling, with the result so commonly seen in prehistoric trephined skulls. (b, c and d after Lucas-Championniére.)

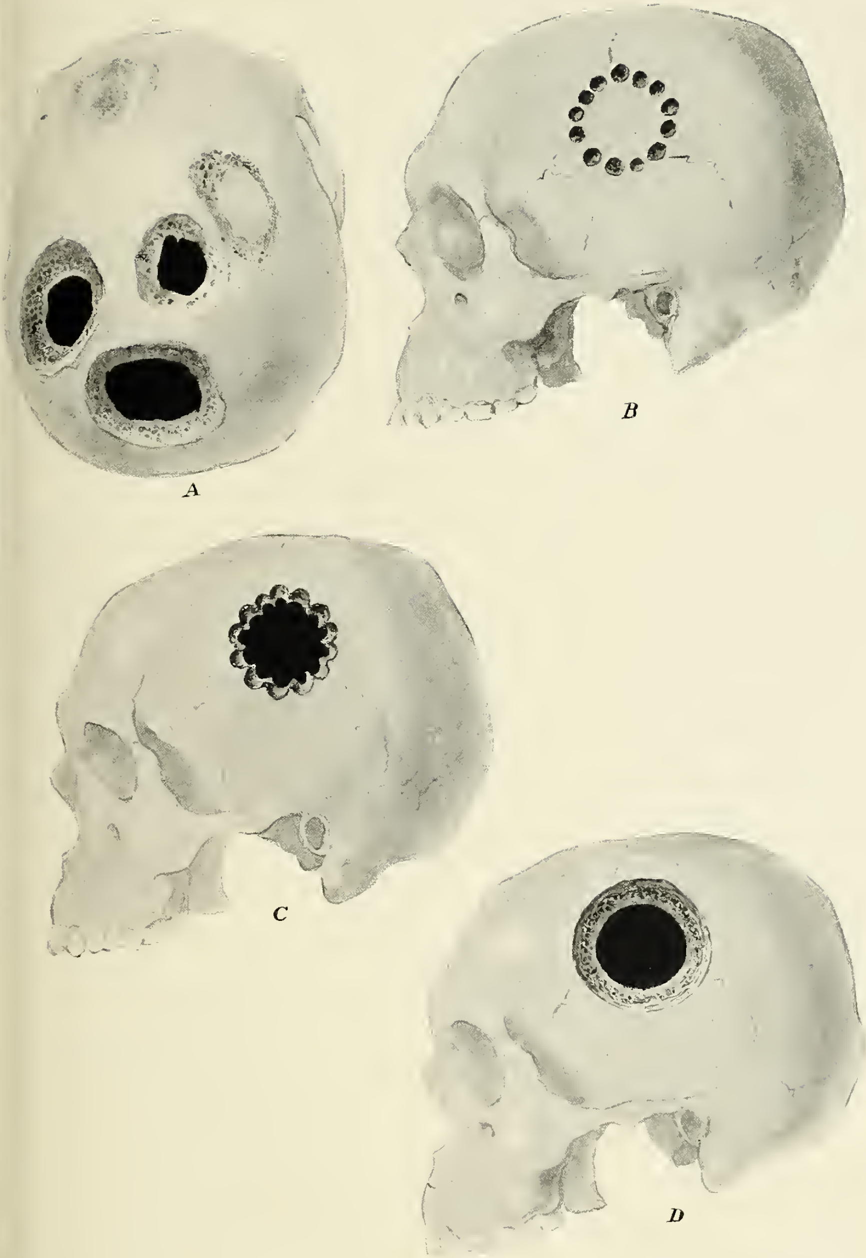


PLATE CVIII

PLATE CIX

PLATE CIX

ANCIENT PERUVIAN PATHOLOGY

a. Skull of a Peruvian mummy showing an unusual type of trepanation. On the basis of this skull Dr. Lucas-Championniére devised the scheme of prehistoric trepanation shown in figures b, c and d Plate CVIII. The original mummy is in the Musée du Trocadéro, Paris. When discovered the skin covered the trephine opening like an operculum. This is the only example known of an ancient Peruvian skull with this type of trephined opening. (Drawn from a photograph by Professor Verneau, After Lucas-Championniére.)

b. A pre-Columbian skull from Peru showing a trephine opening in the frontal bone, and exhibiting the extent to which the operation was often carried. The patient apparently survived the operations which resulted in such an enormous injury, since the margins of the opening show signs of healing, indicating by the smooth margins of the lesion the growth of new bone. Original in the American Museum of Natural History. Courtesy of Mr. C. W. Mead.

c. A pre-Columbian Indian skull from Peru, showing effects of process of trephining by scraping a wide area, indicated by the flat surface on the frontal bone, which has been denuded in the process. The opening was made near the left margin. The region apparently became septic for the bridge of the nose shows considerable hyperplasia. The individual doubtless survived the operation a long time for the margins of the opening are healed over. Collected in the central mountainous part of Peru within 150 miles of the coast by Dr. Aleš Hrdlička. Original in the U. S. National Museum.

d. The Famous Squier's Trephined Skull from Peru. Original in the American Museum of Natural History.

This is the skull that first let the world know that this operation was done in prehistoric Peru—described by Squiers.

Extract of a paper presented by M. Broca to the Anthropological Society of Paris. Trans. by Mr. C. W. Mead.

"Walls of skull are very thick, and it presents characteristics which could only belong to an Indian of Peru and I shall proceed to show that the trepanning was practiced during life.

"Upon the left side of the external plate of the frontal bone there is a large white spot slightly elliptical, 42 mm. long and 47 broad. The outlines of this spot are not irregular or sinuous. The surface is smooth and presents the appearance of an entirely normal bone. Around this, to the edges, the general color of the skull is notably browner, and is perforated by a great number of small holes, caused by dilapidation of the canaliculi. The line of demarkation between the smooth and cribriform surfaces is abrupt, and it is perfectly certain that the smooth surface has been denuded of its periosteum several days before death. It is thus, in truth, that denudations of the cranium behave. In the denuded points, the superficial layer of the external table, deprived of vessels, and thus deprived of life, undergoes no change, and preserves the normal structure; while the surrounding parts in undergoing the effects of traumatic inflammation, become the seat of the osteitis.

"After considering the development of the perforations (porosités) of the external table of the denuded surface, it seems to me impossible to admit that the subject could have survived the denudation less than 7 or 8 days."

M. Nélaton who examined the specimen thinks he may have survived fifteen days.

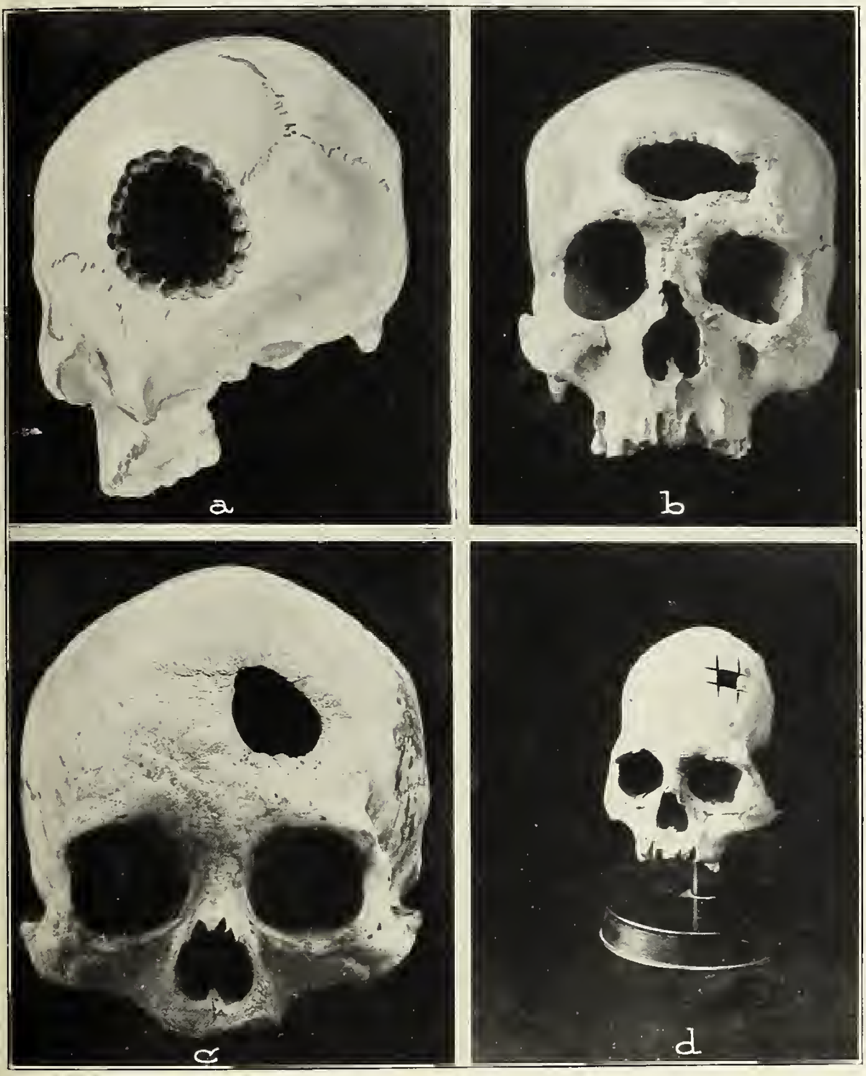


Plate CIX

PLATE CX

PLATE CX

ANCIENT PERUVIAN PATHOLOGY

a. An ancient pre-Columbian water jar from Peru, showing in the features there depicted the possible effects of surgical interference in the removal of the upper lip in an attempt to arrest the progress of the disease known as Uta. Original in the American Museum of Natural History.

b. An ancient Peruvian skull exhibiting an Aymara type of deformation, caused by binding the head of the individual while young. He had suffered a transverse fracture involving the coronal suture, for the relief of which the skull had been unsuccessfully trephined. Original in the American Museum of Natural History.

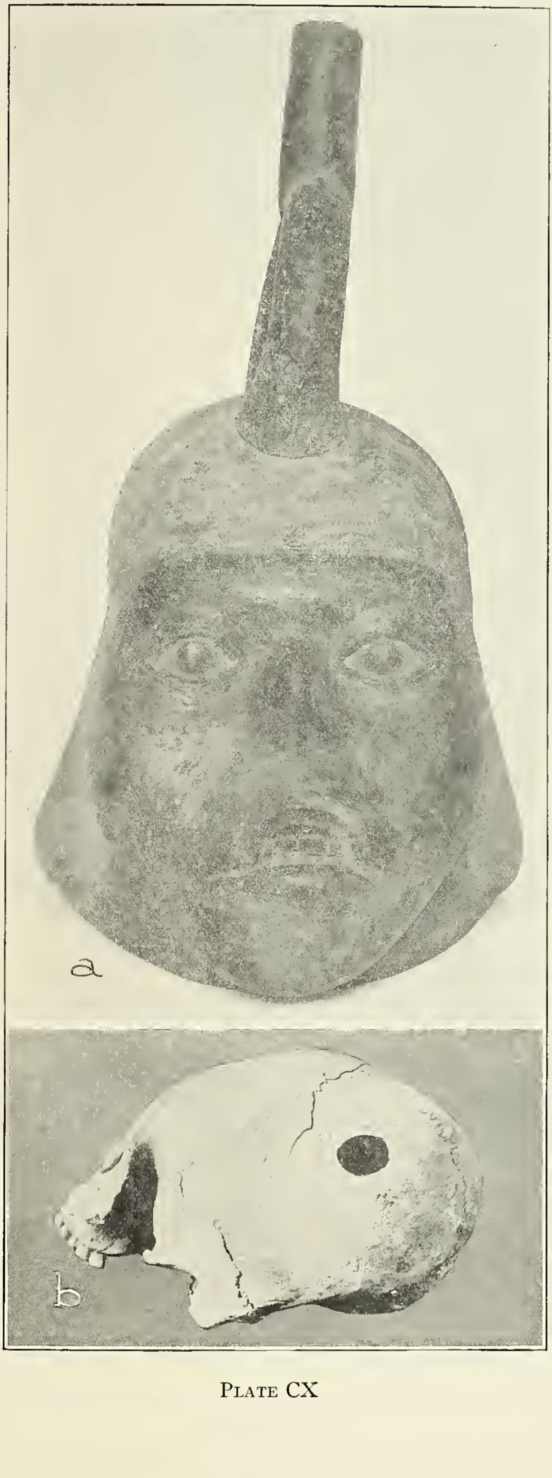


Plate CX

PLATE CXI

PLATE CXI

a. An ancient Peruvian water jar from Chimbote, Peru, collected by Bandelier, showing a swelling at the base of the nose characteristic of goundou of the present day, a disease prevalent in Africa and Malaysia. Original in the American Museum of Natural History through whose courtesy the photograph is published.

b, c, d, e, f. Ancient Peruvian water jars from Peru. The artist doubtless had as models Indians afflicted with *Uta* or *Leishmaniasis*, a disease very prevalent in Peru today. The disease has eaten away the upper lip, exposing the teeth, and the nasal cartilages are partly destroyed. Original in the American Museum of Natural History. Photograph from Mr. C. W. Mead.

PLATE CXI

PLATE CXII

PLATE CXII

a. Small water jar representation of an achondroplastic dwarf on whose body are seen the nodular eruptions of verruga. After Ashmead.

b. Evidence of gondou in ancient Peru.

c. These ancient Peruvian water jars show the seated figures examining the soles of their feet, in which there are holes left after taking out the egg sacs of the sand flea "nigua." Original in American Museum of Natural History.

d. An example of ancient Peruvian pottery showing an amputated leg, at the tibio-tarsal junction, with a cap of painted bone, or wood or metal, in the right hand of the figure to adjust to the stump of the leg. Collected at Chimbote, Peru, by Bandelier. Original in American Museum of Natural History.

Plate CXII

PLATE CXIII

PLATE CXIII

Arthritis deformans of the Hip-joint among the ancient Peruvians. Pelvic bone and Femur on right from one subject. Femur on left shows early Stage of Alterations; that in middle represents a very advanced case of flat "Mushroom-head," that on right a pronounced *Caput penis* condition. All from the Chimu Region, Peru. (After Hrdlička.)

Plate CXIII

PLATE CXIV

PLATE CXIV

A skull with an excessive and peculiar fronto-occipital or "flat-head" deformation, from Chavina, on the Rio de Acari, Peru. (After Hrdlička.)

Plate CXIV

PLATE CXV

PLATE CXV

Adult pre-Columbian Peruvian male skull from the valley of the Chicama, showing recovery from and the remains of symmetric osteoporosis in infancy. (After Hrdlička.)

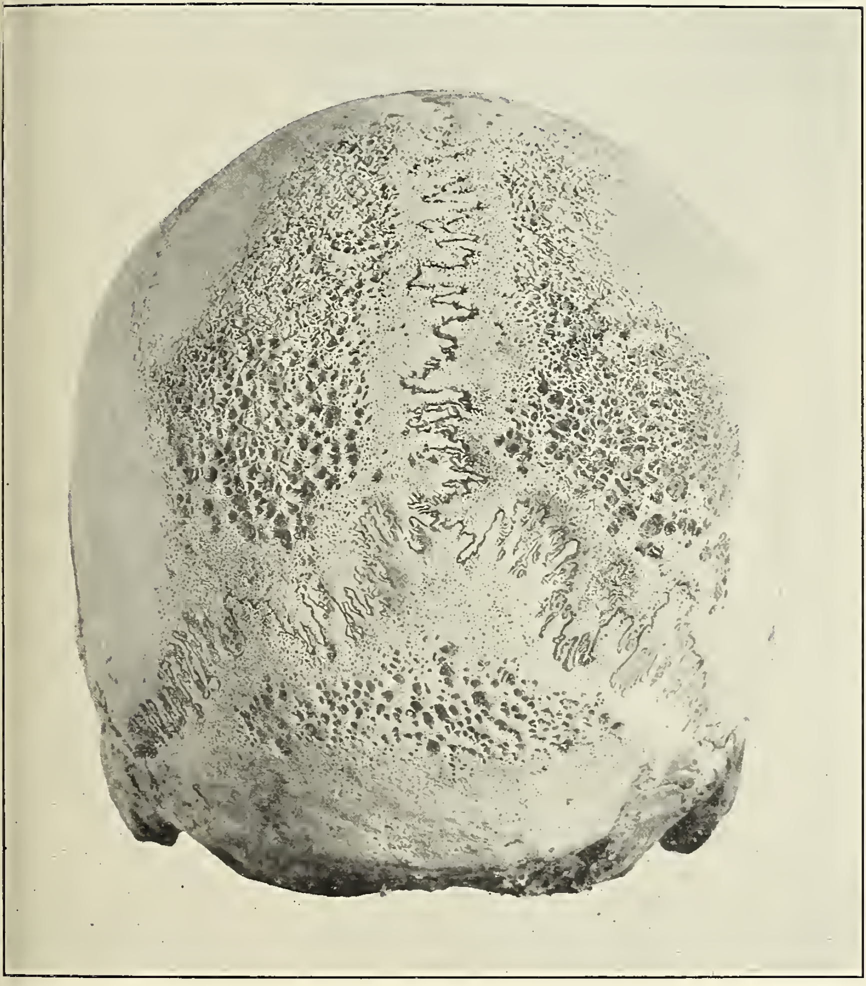


Plate CXV

PLATE CXVI

PLATE CXVI

Parts of three Skulls of Infants, showing Lesions of symmetric Osteoporosis. The middle Skull is from an ancient Burial near Huacho, Peru, while the two Frontals on Sides are from prehistoric Pueblo Cemeteries in Arizona. (After Hrdlička.)

Plate CXVI

PLATE CXVII

PLATE CXVII

Left. Humerus of Orang with pathological lower end. Peabody Museum of Harvard University.

Right. Lumbar and sacral vertebrae of a Peruvian Indian, anterior view showing spondylitis deformans. No. 59444, Peabody Museum of Harvard University.

Plate CXVII

BIBLIOGRAPHY

BIBLIOGRAPHY

This Bibliography contains only references to paleopathology, incidental references, not bearing directly on actual descriptions of ancient lesions, are given in footnotes throughout the text. The form of the references throughout the book have been made to conform, as far as possible, to the "Alphabetical List of Abbreviations of Titles of Medical Periodicals employed in the Index-Catalogue of the Library of the Surgeon General's Office, United States Army," 1916, and to the "Suggestions to Authors of Papers submitted for Publication by the United States Geological Survey," 1916.

Abel, O.
1912 Grundzüge der Palæobiologie der Wirbeltiere. Stuttgart, 8vo. Spuren von Kämpfen, 88–91. Knochenerkrankungen, 91–95.

Auer, E.
1909 Ueber einige Krokodile der Juraformation. Palæontographica, lv, 217–294, 4 pls.

Bandelier, A. F.
1904 Aboriginal Trephining in Bolivia. Amer. Anthrop., vi, 440–446.

Barrell, Joseph
1917 Rhythms and the Measurements of Geologic Time. Bull. Geol. Soc. Am., xxviii, 745–904, 3 pls.

Bartels, Paul
1907 Tuberkulose (Wirbelkaries) in der jüngeren Steinheit. Archiv f. Anthrop., N. F., vi, 243–255.

Bassler, Ray S.
1908 The Formation of Geodes with Remarks on the Silification of Fossils. Proc. U. S. Nat. Mus., Wash., xxxv, 133–154, 6 pls.

Batujeff, N.
1896 Carabelli's Höckerchen und andere unbeständige Höcker der oberen Mahlzähne bei dem Menschen und Affen. Bull. Acad. imp. Sc., St. Petersburg, v, 93–109.

Beecher, C. E.
1884 Some abnormal and pathologic Forms of fresh-water shells from the vicinity of Albany, N. Y., 36th Ann. Rpt., N. Y. State Mus. Nat. Hist., 51–55, 2 pls.
1901 Origin and Significance of Spines. In "Studies in Evolution," N. Y., 8vo, 3–108.
1902 The Reconstruction of a Cretaceous Dinosaur, Claosaurus annectens. Tr. Connect. Acad. Arts & Sc., N. Haven, xi, 322, pl. 44, fig. 1.

BERRY, EDWARD W.
1916 Remarkable fossil Fungi. Mycologia, viii, 73–78, 2 pls.

BLOCH, IWAN
1911 Die Knochenfunde aus prähistorischer und präcolumbischer Zeit. In "Der Ursprung der Syphilis. Eine medizinische und kulturgeschichtliche Untersuchung." Abth. ii, 317–364.

BRANDT, J. F.
1873 Untersuchung über die fossilen und subfossilen Cetaceen Europas. Mem. Acad. St. Petersburg, xx, no. i.

BREASTED, J. H.
1909 History of Egypt, 597–601.
1916 Ancient Times. A History of the early World, Boston, 18, fig. 12; 29, fig. 19.

BRÜHL, GUSTAVUS
1880 On the pre-Columbian Existence of Syphilis in America. Cincin. Lancet-Clinic, May 29; March 8, 1890.

BUCKLAND, WILLIAM
1823 Reliquiæ Diluvianæ; or, Observations on the Organic Remains contained in Caves, Fissures, and Diluvial Gravel, and on Other Geological Phenomena, attesting the Action of an Universal Deluge. London, 4to.
1837 Geology and Mineralogy considered with Reference to Natural Theology. Treatise VI of the Bridgewater Treatises on the Power, Wisdom and Goodness of God as manifested in the Creation. 2 vols. Philadelphia, 8vo.

BUXTON, L. H. D.
See Ray, M. B. and Buxton, L. H. D., 1914.

CASE, E. C.
1915 The Permo-Carboniferous Red Beds of North America and their Vertebrate Fauna. Carnegie Inst. Wash., Pub., 207, 141.

CLARK, A. H.
Some Cases of abnormal arm structure in recent Crinoids. Proc. U. S. Nat. Mus., Wash., xxxiv, 256-270, figs. 1-5.

CLARKE, JOHN M.
1908 The Beginnings of Dependent Life. N. Y. State Educ. Dept., 1–28, 13 pls.
1911 Early Parasitism. Science N. S., xxxiii, 284–296.
1921 Organic Dependence and Disease: Their Origin and Significance. pp. 1–113; figs. 1–105. New Haven, 8°.

CLARKE, J. W. AND NEWTON, E.
See Newton, E. and Clarke, J. W., 1879.

CLIFT, WILLIAM
1823 On some fossil bones discovered in caverns in the Limestone Quarries of Oreston. Phil. Tr. Roy. Soc. Lond., pl. 8, figs. 1, 2, 3.

COTTE, J. ET C.
1916 Note sur l'état de conservation de restes organisés datant de l'époque énéolithique. Compt. rend. Soc. de biol. Par., lxxix, 1003–1005.

CUVIER, GEORG
1820 Recherches sur les Ossemens fossiles. iv, 396 pl. 30, figs. 6–7; vii, 301, pl. 25, fig. 94.

DARWIN, CHARLES
1897 The Origin of Species by Means of Natural Selection. 6th Edition, 2 vols.

DE MORGAN, J.
1897 Recherches sur les Origines de l'Égypte, 2 vols., Paris.

DERRY, DOUGLAS, E.
1907 Notes on Predynastic Tibiae. J. Anat. & Physiol., xli, 123.
1913 A Case of Hydrocephalus in an Egyptian of the Roman Period. J. Anat. & Physiol., xlvii, pt. iv, 436–458.
1914 Parietal Perforation accompanied with Flattening of the Skull in an ancient Egyptian. J. Anat. & Physiol., xlviii, 417.

DUCKWORTH, W. H. L.
1912 On the Natural Repair of Fractures as seen in the Skeletons of Anthropoid Apes. J. Anat. & Physiol., xlvi, 81–85.

EATON, GEORGE F.
1916 The Collection of osteological Material from Machu Picchu. Mem. Connect. Acad. Arts & Sc., N. Haven, v, 1–96, 39 pls.

ECCLES, R. G.
1909 Parasitism and Natural Selection. A medical Supplement to Darwin's Origin of Species. Med. Rec., N. Y., July 31st.

ESPER, E. J. C.
1774 Ausführliche Nachrichten von neuentdeckten Zoolithen unbekannter vierfüssiger Thiere. Nürnberg.

ETHERIDGE, ROBERT
1880 Observations on the swollen condition of Carboniferous Crinoid Stems. Proc. Nat. Hist. Soc., Glasgow, ix, pt. i, 19–36, 2 pls.

FERGUSON, A. R.
See Ruffer, Sir Marc Armand, 1911.1.

FISCHER, E.
1913 Fossile Hominiden. Handwörterbuch der Naturwissenschaften, iv, 332.

FLEMING, GEORGE
1871 Animal Plagues, their History, Nature and Prevention, 1.

FLETCHER, ROBERT
1882 On prehistoric trephining and cranial amulets. Contrib. N. A. Ethnology, Wash., v, 8, pl. iii.

FOUQUET, M.
Mémoires publiés par les membres de la Société Archéologique Française au Caire, sous la Direction de M. Maspero. (See also footnote 2, Chapter XIII.)

FOWKE, GERARD
1910 Antiquities of central and southeastern Missouri. Bur. Am. Ethnol. Bull. 37.

Freeman, Leonard
1918 Primitive Surgery of the western hemisphere. J. Am. M. Assoc., Chicago lxx, no. 7, 443.

Garrison, F. H.
1917.1 An Introduction to the History of Medicine, Philadelphia. Paleopathology, 50.
1917.2 Memorial Notice of Sir Marc Armand Ruffer. Ann. Med. Hist., N. Y., i, no. 2, 218–220, portrait.

Gilmore, Charles W.
1909 Osteology of the Jurassic Reptile, Camptosaurus, with a Revision of the Species of the Genus, and a Description of 2 new Species. Proc. U. S. Nat. Mus., Wash., xxxvi, 296.
1912 The mounted Skeletons of Camptosaurus in the United States National Museum. Proc. U. S. Nat. Mus., Wash., xli, 689, pls. 56, 58.
1915 On the fore limb of Allosaurus fragilis. Proc. U. S. Nat. Mus., Wash., xlix, 504.

Goldfuss, August
1810 Die Umgebungen von Muggendorf. Erlangen, 276.

Graff, L. von
1885 Ueber einige Deformitäten an fossilen Crinoiden. Palæontographica, xxxi, 183–192, 1 pl.

Hamburger, Ove
1911 Un cas de paralysie infantile dans l'antiquité. Bull. Soc. franç. d'hist. de méd., Par., x, 407–409.

Hatcher, J. B.
1901 Diplodocus Marsh, its Osteology, Taxonomy, and probable Habits, with a restoration of the Skeleton. Mem. Carnegie Mus., Pittsburg, i, 36, fig. 11.
Oligocene Canidæ. Mem. Carnegie Mus., Pittsburg, i, 85, pl. 19, figs. 9, 11.
1907 The Ceratopsia. U. S. Geol. Surv., Wash., Monograph xlix, 124. (With O. C. Marsh and R. S. Lull.)

Hecker, J. F. C.
1846 Epidemics of the Middle Ages, 181–353.

Holland, W. J.
The Osteology of Diplodocus Marsh. Mem. Carnegie Mus., Pittsburg, ii, 255, figs. 23, 24.

Howorth, Henry H.
1887 The Mammoth and the Flood: an Attempt to confront the Theory of Uniformity with the Facts of recent Geology, London, 8vo.

Hrdlička, Aleš
1899 Description of an Ancient Anomalous Skeleton from the Valley of Mexico, with Special Reference to Supernumerary and Bicipital Ribs in Man. Bull. Am. Mus. Nat. Hist., N. Y., xii, 5 pls.
1908.1 Physiological and Medical Observations among the Indians of southwestern United States and northern Mexico. Bur. Am. Ethnol. Bull. 34.
1908.2 Report on a Collection of Crania from Arkansas. J. Acad. Nat. Sc. Phila., xiii, 558–563.

1909.1 Tuberculosis among certain Indian Tribes of the United States. Bur. Am. Ethnol. Bull. 42.
1909.2 Report on an additional collection of skeletal remains from Arkansas and Louisiana. J. Acad. Nat. Sc. Phila., xiv, 173–240, 9 figs.
1911 Some results of recent anthropological explorations in Peru. Smithson. Misc. Collect., Wash., lvi, 1–16. Bibliography on anthropology of Peru.
1912.1 Report on skeletal remains from a mound on Haley Place, near Red River, Miller Co., Arkansas. J. Acad. Nat. Sc. Phila., xiv, 639–640.
1912.2 Early Man in South America. Bur. Am. Ethnol. Bull. 52 (with Holmes, Willis, Wright and Fenner).
1913 A Report on a collection of Crania and Bones from Sorrel Bayou, Iberville Parish, Louisiana. J. Acad. Nat. Sc. Phila., xvi, 95–99.
1914 Anthropological Work in Peru in 1913, with notes on the Pathology of the ancient Peruvians. Smithson. Misc. Collect., lxi, no. 18, 1–69, 26 pls.
1916 The most ancient Skeletal Remains of Man. Smithson. Rpt., for 1913, 491–552, pl. 4.

Huene, Friedrich von
1911 Beiträge zur Kenntnis und Beurteilung der Parasuchier. Geol. u. Paleontol. Abhandl., Tübingen, N. F., x, heft 1, 5, pl. 1.

Huxley, T. H.
1862 Geological Contemporaneity and Persistent Types of Life. Address to Geological Society. Scientific Memoirs, ii, 90–93; Proc. Roy. Inst. Great Britain, iii, 151–153, 1858.
1869 Presidential Address, Geol. Soc. London, Quart. J. Geol. Soc., Lond., xxv, xxxviii–liii.

Hyde, J. B.
1891 A Contribution to the Study of pre-Columbian Syphilis in America. Am. J. M. Sc., Phila., 117–131.

Jackson, J. Wilfrid
1914 Dental Mutilations in Neolithic Human Remains. J. Anat. & Physiol., xlix, 72–79.

Jeanselme, E.
1918 De l'Existence du Tubercle de Carabelli aux Epoches Paléolithique et Néolithique dans l'Antiquité Classique et au Moyen Âge. Bull. et mém. d. Soc. méd. d. hôp. de Par., 34 Annee, no. 1–2, 51–52. Also Bull. Acad. de Méd., Paris, 1918, 3 s., lxxix, 55–59. (Rev: Am. J. Physical Anthrop., Wash., i, no. 2, 239; Ann. Med. Hist., N. Y., 1, no. 4.)

Jones, F. Wood
1908.1 The post-mortem staining of bone produced by the ante-mortem shedding of blood. Brit. M. J., Lond., i, 734–736.
1908.2 The Examination of the Bodies of 100 men executed in Nubia in Roman Times. Brit. M. J., Lond., March 28, i, 736.
1910 VII. General Pathology, including Diseases of the Teeth, 263–292. VIII. Fractures and Dislocations, 293–342. In "Report Archeological Survey of Nubia," 1907–8, ii, 49 pls. See Smith, G. Elliot, 1910.1.

Keith, Arthur
1913 Abnormal Crania-Achondroplastic and Acrocephalic. J. Anat. & Physiol., xlvii, 189–206.
1916 The Antiquity of Man, London, 21, 79, 118, 137.

Klebs, Arnold C.
1917.1 Palæopathology. Johns Hopkins Hosp. Bull., Balt., xxviii, 261–266.
1917.2 Palæopathology. Boston M. & S. J., clxxvi, 364–365.

Lamb, D. S.
1898 Pre-Columbian Syphilis. Proc. Assn. Am. Anat., x, 63.

Langdon, F. W.
1881 The Madisonville prehistoric cemetery, anthropological notes. J. Cincin. Soc. Nat. Hist., iii, 40–68; 128–139; 203–220; iv, 250–253.

Lapworth, A. and Royle, F. A.
1914 The Lipoids of Ancient Egyptian Brains and the nature of Cholesteryl Esters. J. Path. & Bacteriol., xix, 474–477.

Larcher, O.
Pathologie comparée. Dictionnaire encyclopédique des Sciences Médicales, xxi, 601–628.
1911 De l'extinction des espèces par la dégénérescence ou maladie des rameaux phyletiques.
Bull. soc. Hist. Nat. Haute Marne. I, p. 49; also Bull. Soc. Geol. France (4) X, 631–533, 1910.

Larger, René
1916.1 L'Acromégalie-Gigantisme, cause naturelle de la dégénérescence et, partant, de l'extinction des groupes actuels et fossiles (Read 3 fevrier, 1916, but not published).
1916.2 La contre évolution or dégénérescence par l'hérédité pathologique cause naturelle de l'extinction des groupes animaux. Essai de paleopathologique générale comparée. Bull. et mém. Soc. d'anthrop. de Par. 1916.

Le Baron, Jules
1881.1 Lésions osseuses de l'homme préhistorique en France et an Algérie. Paris, 1–118. (Thése pour le Doctorat en Médicine, No. 262.)
1881. 2 Sur les lésions osseuses préhistoriques. Bull. de la Soc. d'Anthrop. de Paris, 3; série. IV, 597–598.

Leidy, Joseph
1873 Contributions to the extinct Vertebrate Fauna of the western territories. Washington, U. S. Geol. Surv. Terr., 208, pl. ii, fig. 15.
1886 Caries in the Mastodon. Proc. Acad. Nat. Sc. Phila., 38.

Lémiére, L.
1900 Transformation des végétaux en combustibles fossiles. Essai sur le rôle des ferments. Congrés géol. internat. de 1900, Par., i, 502–520.

Lortet, L. C.
1903–1909 La Faune momifiée de l'ancienne Égypte. Arch. d. Mus. d'Hist. nat. de Lyon, ix, 29, (With C. Gaillard.)
1911 La Vie et les Travaux de Louis Charles Lortet, par M. Claude Gaillard. Arch. d. Mus. d'Hist. nat. de Lyon, xi, 1–31, portrait.

Lucas, F. A.
1901 The Dinosaurs or Terrible Lizards. Smithson. Rpt., 1901, 645.

Lull, R. S.
1907 The Ceratopsia. U. S. Geol. Surv., Wash., Monograph xlix, (With J. B. Hatcher and O. C. Marsh).
1917 Organic Evolution, N. Y., 409–420.

Lyell, Sir Charles
1867 Principles of Geology, London, 2 vols, 10th Ed.

Mair, W.
1914 On the Lipoids of ancient Egyptian Brains. J. Path. & Bacteriol., xviii, 179.

Manouvrier, M.
1903 Deux trépanations craniennes préhistoriques avec longue survie et déformations consécutives. Bull. et mém. Soc. d'anthrop. de Par., 404–417, 2 figs.

Marotel, G.
1909 The Relation of mosquitoes, flies, ticks, fleas, and other arthropods to pathology. Annl. Rpt. Smithson. Inst., Wash., 703–722.

Marsh, O. C.
See J. B. Hatcher, 1907.

Matthew, W. D.
1914 Time Ratios in the Evolution of the mammalian Phyla. A Contribution to the Problem of the Age of the Earth. Science, N. Y. & Lancaster, xl, 232–235.

Mayer, Dr.
1854 Ueber krankhafter Knochen vorweltlicher Thiere. Nova Acta Leopoldina, xxiv, pt. ii, 673–689, pl. 30.

Merriam, J. C.
1911 The Fauna of the Rancho la Brea. Mem. Univ. California, Berkeley, i, no. 2.

Metchnikoff, Elié
1905 Immunity in infectious Diseases; translated from the French by Francis G. Binnie, 18, Chap. iii.

Moodie, Roy L.
1916.1 Bacteriologic and Pathologic Evidences in past Geologic Ages. Tr. Chicago Path. Soc., 84–88.
1916.2 Mesozoic Pathology and Bacteriology. Science, N. Y. & Lancaster, N. S. xliii, 425.
1916.3 Two caudal Vertebrae of a sauropodous Dinosaur exhibiting a pathological Lesion. Am. J. Sc., N. Haven, xli, 530.
1917 The Influence of Disease in the Extinction of Races. Science, N. Y. & Lancaster, N. S., xlv, 63.
1918.1 Pathological Lesions among extinct Animals: A Study of the Evidences of Disease Millions of Years Ago. Surg. Clin. Chicago, ii, 319–331, 8 figs. (Rev: Med. Rec., N. Y. Sept. 14th, 1918, 474.)
1918.2 Paleontological Evidences of the Antiquity of Disease. Scient. Month., N. Y., vii, 265–282, 21 figs. (Rev; Boston M. & S. J., clxxix, 459). (Referred to under heading: "The Antiquity of Disease." J. Am. Med. Assn., Chicago, lxxi, 1829.)
1918.3 Studies in Paleopathology. I. General Consideration of the Evidences of pathological Conditions found among fossil Animals. Ann. Med. Hist., N. Y., i, no. 4, 374–393, 20 figs.
1918.4 The Tubercle of Carabelli and congenital Syphilis. Ann. Med. Hist., N. Y., i, no. 4, 423–424.
1918.5 Studies in Paleopathology. II. Pathological Evidences of Disease among ancient Races of Man and extinct Animals. Surg. Gynec. & Obst., Chicago, 498–510, 45 figs. Abstract: So. Med. Jour., xii, 128, 1919.

1918.6 Studies in Paleopathology. III. Opisthotonos and allied Phenomena among fossil Vertebrates. Am. Naturalist, lii, 384–394, 8 figs.
1918.7 On the Parasitism of Carboniferous Crinoids. J. Parasitol., Urbana, Ill., iv, 174–176.
1918.8 Diseases of the Mosasaurs. Bull. Geol. Soc. Am., xxix, 147.
1918.9 Synthesis of Paleontology and Medical History. Science, N. Y. & Lancaster, XLVIII, 619–620.
1919.1 Paleopathology. So Med. J., xii, no. 4, 182–184.
1919.2 Ancient Skull Lesions and the Practice of Trephining in Prehistoric Times. Surg. Clin. Chicago, iii, 481–496, figs. 139–149.
1919.3 Opisthotonos. Science, N. S. 50, 275–276.
1920.1 Thread Mould and Bacteria in the Devonian. Science, N. S., li, 14–15.
1920.2 Studies in Paleopathology. IV. The Diseases of the ancient Peruvians, and some Account of their Surgical Practice. Surg. Clin. Chicago, iv, no. 1, 211–231, figs. 72–83.
1920.3 New Observations in Paleopathology. Ann. Med. Hist., N. Y., ii, 241–247.
1920.4 Primitive Surgery in ancient Egypt. Surg. Clin. Chicago, iv, no. 2, 349–358, figs. 121–128.
1920.5 The Antiquity of Pott's Disease and other Spinal Lesions: Primitive Treatment. Surg. Clin. Chicago. iv, no. 3, 619–627, 3 figs.
1920.6 The Use of the Cautery among Neolithic and later primitive Peoples. Surg. Clin. Chicago, iv, no. 4, 851–862, 3 figs.
1920.7 Surgery and Disease among the pre-Columbian Indians of North America. Surg. Clin. Chicago, iv, no. 5, 1091–1102, 13 figs.
1920.8. Amputation of the Fingers by Neolithic and modern primitive Races, and other voluntary mutilations indicating some knowledge of Surgery. Surg. Clin. Chicago, iv, no. 6, 1299–1306, 4 figs.
1921.1 A Variant of the Sincipital T from Peru. Am. J. Phys. Anthropol., iv, 219–222, 2 pls.
1921.2 The Status of our Knowledge of Mesozoic Pathology. Bull. Geol. Soc. Amer., xxxii, 321–326.
1921.3 Osteomyelitis in the Permian. Science, N. S., liii, No. 1371, 333.
1921.4 Bacteria in the American Permian. Science, N. S., liv, 194–195.
1921.5 Disease and Injury in fossil Men and the Beginnings of Surgery. Sci. Monthly, xiv, 391–394, 3 figs.
1921.6 Recent Advances in Paleopathology. Science, N. S., liv, 664.
1921.7 Stone Age Man's Cure for Headache. Sci. Monthly, Feby.
1922. 1 Actinomycosis in a fossil Rhinoceros. J. Parasitology, Urbana, Ill., ix, No. 1, 28. September.
1922. 2 The Paleopathology of the Parasuchians. Science, N. S., LVI, 417.

Morgan, Edward L.
1893 Syphilis—its Age and Relation to the Antiquity of Man. Virginia M. Semi-Month., Richmond, xx, 166.
1894 Pre-Columbian Syphilis. Virginia M. Semi-Month., Richmond, xxi, 1042.

Newton, A. and Newton, E.
1870 On the Osteology of the Solitaire or Didine Bird of the Island of Rodriguez, *Pezophaps solitaria* (Gmel.). Phil. Tr. Roy. Soc. London, clix, 327–362.

Newton E. and Clark, J. W.
1879 On the Osteology of the Solitaire, *Pezophaps solitaria* (Gmel.). Phil. Tr. Roy. Soc. London, clxviii, 428–451.

Oefele, Felix von
1902 Studien ueber die altaegyptische Parasitologie. Archives de Parasitologie, v. 499–503, Paris.

Orton, S. T.
1905 A Study of the pathological Changes in some Mound-Builders' Bones from the Ohio Valley, with especial Reference to Syphilis. Univ. Penn. M. Bull., Phila., xviii, 36–44.

Osborn, H. F.
1895 Perissodactyls of the Lower Miocene White River Beds. Bull. Am. Mus. Nat. Hist., N. Y., vii, 351.
1906 The Causes of Extinction of Mammalia. Am. Naturalist, xl. 769–795; 829–859.
1910 The Age of Mammals in Europe, Asia, and North America. N. Y., 8vo, 285, 507.
1915 Men of the Old Stone Age, their Environment, Life, and Art. N. Y., 8vo, 41.
1917 The Origin and Evolution of Life, on the Theory of Action, Reaction and Interaction of Energy, N. Y., 8vo, 85.

Owen, Sir Richard
1842 Description of the Skeleton of an extinct gigantic Sloth, Mylodon robustus Owen, with Observations on the Osteology, Natural Affinities, and probable Habits of the Megatheroid Quadrupeds in General. London, 4to.

Pagel, J. and Sudhoff, K.
1915 Einführung in die Geschichte der Medizin, 33.

Parker, Charles A.
1904 Evidences of rheumatoid Arthritis in the Lansing Man. Am. Geol., xxxiii, 39–42, 1 fig.

Pettigrew, Th. J.
1834 A History of Egyptian Mummies, London, 8vo.

Poncet, A.
1909 Déformations osseuses pathologiques. Arch. d'Mus. d'Hist. nat. de Lyon, ix, 26–31, 6 figs.

Pusey, W. A.
1915 The Beginnings of Syphilis. J. Am. M. Assn., Chicago, lxiv, 1961–1963.

Raspail, F. V.
1860 Histoire naturelle de la Santé et de la maladie chez les végétaux et chez les animaux en général, Paris.

Ray, M. B. & Buxton, L. H. D.
1914 Some pathological and other conditions observed among the human remains from a prehistoric Ethiopian cemetery in southern Sudan, Africa. Proc. xvii Internat. Cong. Med. 1913, Lond., 1914, Sect. xxiii, 231–236.

Raymond, Paul
1912 Les maladies de nos ancêtres a l'age de la pierre. Æsculape, Par., ii, 121.

Renault, Bernard
1895.1 Sur quelques bactéries des temps primaires, Bull. de Mus. d'Hist. Nat., Par. 1, no. 4, pp. 168–172, 4 figs.
1895.2 Sur quelques bactéries anciennes. Bull. de Mus. d'Hist. Nat., Tome 1, 247–252, 6 figs.
1895.3 Sur quelques bactéries du Dinantian (Culm). C. R. des sé de l'Acad. des Sci. Par. 120, 162–164.

1896.1 Recherches sur les bactériacées fossiles. Ann. des sci. nat. bot., viii série, 2, 275–349.
1896.2 Les Bactéries dévoniennes et le genre Aporoxylon d'Unger. Bull. d. Mus. d'Hist. Nat. Paris, 201–203.
1896.3 Notes sur quelques nouvelles bactéries fossiles. Bull. d. Mus. d'Hist. nat. Par., 2, 285–288, 4 figs.
1896.4 Les Bactéries dévoniennes et le genré Aporoxylon d'Unger. Bull. de la Soc. d'Hist. nat. d'Autun. 9, 139–142.
1896.5 Houille et Bactériacées. Bull. Soc. d'Hist. nat. d'Autun. 475–500, 1 pl.
1896.6 Les Bactériacées de la houille. C. R. des sé. de l'Acad. des sci. Par. 123, pp. 935–955.
1896.7 Sur quelques Bactéries dévonennes. C. R. des sé. de l'Acad. des sci. Par. 122, pp. 1226–1227.
1897.1 Les Bactériacées et les bogheads á Pilas. Bull. du Mus. d'Hist. nat. Par., 3, 33–39, 4 figs.
1897.2 Les Bactériacées des bogheads. Bull. du Mus. d'Hist. nat. Par., 3, 251–258, 6 figs.
1897.3 Bogheads et bactériacées. Bull. d. Soc. d'Hist. nat. d'Autun., x, 433–469, 18 text figures.
1897.4 Les Bactériacées des bogheads. C. R. des sé. de l'Acad. des sci. Par., 124, pp. 1315–1318.
1898.1 Les microorganismes des lignites. C. R. des sé. de l'Acad. des sci. Par., 126, 1828–1831.
1898.2 Du mode de propogation des bactériacées dans les combustibles fossiles et du rôle qu'elles ont joué dans leur formation. Bull. d. Soc. d'Hist. nat. d'Autun, 9, pp. 133–147 (In the Procés verbeaux). (With A. Roche.)
1899–1900 Microorganismes des combustibles fossiles. Bull. d. la Soc. d. l'Industrie minérale á Saint-Etienne. Série III, 1899. Tome 13, pp. 865–1,161; Tome 14, pp. 5–159. 1900 with atlas (1898–1899). pls. x–xxv; Atlas 1900–1901, pls. i–v.

Rietta, Arnoldo
See Ruffer, Sir Marc Armand, 1912.

Riggs, E. S.
1903 Structure and Relationship of the opisthocoelian Dinosaurs. Part I, Apatosaurus. Field Museum, Chicago, Pub. 82, 177.

Ruedemann, Rudolf
1916 The Paleontology of arrested Evolution. N. Y. State Mus., Bull. 196, 107–134.

Ruffer, Sir Marc Armand
1909 Preliminary Note on the Histology of Egyptian Mummies. Brit. M. J., Lond., i, 1005.
1910.1 Pott'sche Krankheit an einer ägyptischen Mumie aus der Zeit der 21 Dynastie (um 1000 v. Chr.) Zur historischen Biol. d. Krankheitserreger 3, 9–16, 2 plates (With G. Elliot Smith).
1910.2 Remarks on the Histology and pathological Anatomy of Egyptian Mummies. Cairo Sc. J., no. 40, iv, 1–5, January.
1910.3 Note on the Presence of "Bilharzia haematobia" in Egyptian Mummies of the twentieth Dynasty (1250–1000 B. C.) Brit. M. J., 1, 16.
1911.1 On arterial Lesions found in Egyptian Mummies. J. Path & Bacteriol., xv, 453–462, 2 plates.

1911.2 Note on an Eruption resembling that of Variola in the Skin of a Mummy of the Twentieth Dynasty (1200–1100 B. C.) J. Path. & Bacteriol., xv, 1-3, 1 plate. (With A. R. Ferguson.)
1911.3 On Dwarfs and other deformed Persons in ancient Egypt. Bull. Soc. Archéol. d'Alexandrie, No. 13, 1–17, 5 plates.
1911.4 Histological Studies on Egyptian Mummies. Mém. prés. á l'Inst. Égypt., Le Caire, vii, 1–40, 11 plates.
1912.1 On osseous Lesions in ancient Egyptians. J. Path. & Bacteriol., xvi, 439–466, 8 plates. (With Arnoldo Rietti.)
1913.1 Studies in Palaeopathology in Egypt. J. Path. & Bacteriol., xviii, 149–162, 6 plates.
1914.1 Studies in Palaeopathology. Note on the Diseases of the Sudan and Nubia in ancient Times. Mitt. z. Gesch. d. Med. u. d. Naturw., Hamb. & Leipz., xiii, 453–460 (1913–1914).
1914.2 Pathological notes on the Royal Mummies of the Cairo Museum. Mitt. z. Gesch. d. Med. u. d. Naturw., Hamb. & Leipz., xiii, 239–268.
1914.3 Studies in Palaeopathology. Note on a Tumor of the Pelvis dating from Roman Times (250 A. D.) and found in Egypt. J. Path. & Bacteriol., xviii, 480–484, 2 plates.
1917 A Pathological Specimen dating from the Lower Miocene Period (Extrait de "Contributions á l'Étude des Vertébrés miocénes de l'Égypte.) Cairo, Survey Dept., 1917, 2 pls. 7 pp.
1918.1 Some recent researches on prehistoric Trephining. Jour. Path. Bacteriol., xxii, 90–104, 1 fig.
1918.2 Arthritis deformans and spondylitis in ancient Egypt. Jour. Path. Bacteriol., xxii, 152–196, 6 pls.
1920 Abnormalities and Pathology of ancient Egyptian Teeth. Amer. Jour. Phys. Anthrop., III, 335–382, 8 pls.
1921 Studies in the Paleopathology of Egypt. University of Chicago Press, edited by Roy L. Moodie, pp. i-xx and 1–372, 71 plates. This work contains reprints of most of Ruffer's studies in paleopathology.

Of accessory importance are the following:

1919.1 Food in Egypt. Mémoires présentés á l'Institut Égyptien. I, 1–88.
1919.2 On the physical effects of consanguineous Marriages in the royal Families of ancient Egypt. Proc. Roy. Soc. of Med., Sect. of Hist. of Med., London, xii, 1–46, 27 figs.

SCHAAFHAUSEN, D.
1858 Zur Kenntnis der ältesten Rassenschädel. Arch. f. Anat. Physiol. u. Wissen. Med. 453–478, 1 pl. See also: Nat. Hist. Rev., London, 1861, 155–176, 2 pls.

SCHLOSSER, MAX
1909 Die Bären- oder Tischofer-höhle im Kaiserthal bei Kufstein. Abhandl. d. math.-phys. Cl.d.k. bayer. Akad. d. Wissensch., Munich, xxiv. 385–506, 5 pls.

SCHMERLING, P. C.
1835 Description des ossemens fossiles, á l'état pathologique, provenant des caverns de la province de Liége. Bull. Soc. géol. de France, vii, 51–61.
1883 Recherches sur les ossemens fossiles. Chap. xi, "Des ossemens fossiles á l'état pathologique." Liége.

Schwalbe, G.
1901 Ueber die spezifischen Merkmale des Neanderthalschädels. Verhandl. d. Anat. Gesellsch., Jena, 440–461.

Shattock,
1909 Microscopic Sections of the Aorta of King Merneptheh. Lancet, Lond., 319.

Smith, G. Elliot
1906 A Contribution to the Study of Mummification in Egypt with special Reference to the Measures adopted during the time of the xxist Dynasty for moulding the Form of the Body. Mém. prés. á l'Instit. Egypt., v, 1–53, 19 pls.
1907 Report on the unrolling of the Mummies of the Kings Siptah, Seti II, Rameses IV, Rameses V, and Rameses VI. Bull. de l'Instit. Egypt., 5e série, i.
1908.1 The Unwrapping of Pharaoh. Brit. M. J., Lond., i, 342.
1908.2 The most ancient splints. Brit. M. J., Lond., i, 732–734.
1908.3 Medical Egyptology. Brit. M. J., Lond., i, 769.
1908.4 Notes on Mummies. Brit. M. J., Lond., i, 1062.
1910.1 Report on Human Remains. The Archeological Survey of Nubia. Report for 1907–08, ii, 1–375, with folio atlas of 49 pls. issued by Ministry of Finance, Egyptian Survey Department, Cairo. (With F. Wood Jones.)
1910.2 Pott'sche Krankheit an einer aegyptischen Mumie aus der Zeit der 21 Dynastie (um 1000 v. Chr.). Zur historischen Biol. der Krankheitserreger. Heft 3, 9–16, Giessen., 2 pls.
1917 The Origin of the pre-Columbian Civilization of America. Science, N. Y. & Lancaster, N. S., xlv, 241.

Soemmering, S. Th. von
1828 Ueber die geheilte Verletzung eines fossilen Hyänenschädels. Verhandl d.k. Leopold. Carolin. Akad. Naturf., Bonn, 1829, vi, Abth. i, 9.

Steindachner, F.
1859 Beiträge zur Kenntnis der fossilen Fischfauna Oesterreichs. Sitzungsb. d.k. Akad. d. Wissensch., Math.-naturw. Cl., Wien, xxxvii, 685–693, 3 pls.

Stomer von Reichenbach, Ernst
1909 Parasitism. Lehrbuch der Paleozoologie, i, 12, fig. 11B; 109, fig. 128B; 274, 287, 324.

Sudhoff, K.
1909 Medizin in der Steinzeit. Zeitschr. f. ärtzl. Fortbildung, 6 Jahr. Nr. 6, 196–200.
1910 Zur Einführung und Orientierung. (Preface to essay by Ruffer and Smith on Pott's disease in an Egyptian Mummy of the 21st Dynasty (1000 b. c.) Zur historischer Biologie der Krankheitserreger, Heft 3, 3–8.

Thoma, K. H.
1916 Oral Diseases of ancient Nations and Tribes. J. Allied Dent. Soc., N. Y., xii, 327–334, 8 pl. (Rev.: Dental Cosmos, lix, 1162).

Tieghem, Ph., van
1879 Sur la fermentation butyrique (Bacillus amylobacter) á l'epoque de la houille. C. R. des sé. de l'Acad. des sci. Par., lxxxix, 1102–1104.

Troxell, Edward L.
1915 The Vertebrate Fossils of Rock Creek, Texas. Am. J. Sc., N. Haven, xxxix, 626, fig. 14.

VIRCHOW, R.
1870 Ueber einen Besuch der west-fällischen Knochenhöhle. Ztschr. f. Ethnol., Berl., ii, 365, footnote.
1872 Untersuchung des Neanderthal Schädels. Ztschr. f. Ethnol., Berl., iv, 57.
1885 Ueber krankhaft veränderte Knochen alter Peruaner. Sitzungsb. d. k. Preuss. Acad. d. Wissenschft, 1135–1139.
1895.1 Knochen vom Höhlenbären mit krankhaften Veränderungen. Ztschr. f. Ethnol., Berl., xxvii, 706–708, 4 figs.
1895.2 Exostosen und Hyperostosen von extremitäten-knochen des Menschen im Hinblick auf den Pithecanthropus. Ztschr. f. Ethnol., Berl., xxvii, 787–793.
1896 Beitrag zur Geschichte der Lues. Dermat. Ztschr. Berl., iii, 4.

VOLZ, W.
1902 Proneusticosaurus, eine neue Sauropterygier-Gattung aus dem unteren Muschelkalk Oberschliesens. Palæontographica, xlix, 121–162, 2 pls.

WALTHER, PH. FR. VON
1825 Ueber das Alterthum der Knochenkrankheiten. J. d. Chir. u. Augenh., Bonn, viii, 16.

WIELAND, G. R.
1909 Revision of the Protestegidæ. Am. J. Sc., N. Haven, xxvii, 125, pl. 2.

WILDER, H. H.
1904 Restoration of dried tissues, with especial reference to human remains. Am. Anthrop., vi, 1–17.

WILLISTON, S. W.
1898 Mosasaurs. Univ. Geol. Surv. Kansas, iv, pl. lvi, figs. 3–5.
1914 Water Reptiles of the Past and Present, Chicago, 152.

WILLMORE, J. G.
1914 See Ruffer, Sir Marc Armand, 1914.3.

WILSON, THOMAS
1901 Arrow Wounds, Amer. Anthrop., iii, 513–531, 3 pls., 9 figs.

INDEX

Abel, O., 68, 70, 122, 223, 251, 326.
Abscess, subperiosteal, 123.
Abscesses, 224, 402, 422.
Acanthodes gracilis, 340.
Acromegaly, 348, 448.
Actinomyces, 249.
Actinomycosis, 175, 238, 243, 249, 258.
Actinophrys, 35.
Adachi, B., 398.
Adami, J. G., 289.
Aeleurocyon, 126, 154.
Aenocyon dirus, 128, 253.
Aesocrinus, 110.
Agate Spring Quarry, 126.
Aichstädt, 326.
Alethopteris, 105.
Alexander the Great, soldiers of, 430.
Algeria, 22, 352.
Algonkian, 30, 290.
Alligators, 331.
Allosaurus fragilis, 69.
Alveolar osteitis, 86, 221.
Amber of the Baltic, 104, 287.
Ameghino, Florentino, 485.
Amenhotep II, 392.
American Museum of Natural History, 11, 162, 238, 252, 489.
Ammon, Priest of, 424.
Amoebae, 35.
Amputation, 69, 361, 374, 532.
Amulet, cranial, 358, 384.
Ancylostoma duodenale, 287.
Anesthesia, 455.
Aneurism, carotid, 430.
Animals, oldest known, 48.
Ankylosis, 124, 410, 432.
Anning, Miss Mary, 328.
Annulata, 48.
Anomalies, 223, 240, 254.
Anoplotherium commune, 28, 62.
Ants, fossil, showing parasitism, 287.
Antheridia, 105.
Anthrax, 35.
Anthropology, 221, 358.
Anthropopithecus troglodytes, 225.
Antiquity of disease, 39.
Antrodemus, 154.
Aorta of Mernepthah, 392.
Apatosaurus, fractured rib, 123, 154.
   louisiae, 165, 192.
   tumor in, 162, 180.
Apes, 115, 410, 450.
Aphelops, 258.
Appendicitis, 398.
Archaeopteryx macroura, 326, 331, 340.
Archaeotherium, 126.
Archaeozoic, duration of, 96.
Archelon ischyros, 69, 88.
Armstrong, John M., 169.
Arrow-point injuries, 349, 380.
Arterial lesions, 392, 394.
Arteriosclerosis, 392.
Arthritides, deforming, 86, 161, 169, 432, 468.
Arthritis, multiple, in Mosasaur, 171, 216.
Arthritis deformans, 86, 125, 161, 278, 348, 352, 534.
Ashmead, A. S., 490.
Assuan Dam, 403.
Atheroma, 393.
Auer, Erwin, 71, 90.
Aurignacian caves, 363, 374.
Australian native, 376.
Autun Schists, 221, 294, 295, 318.
Aymara, 356, 486, 514.
Aysheaia pedunculata, 48.

Baboon, 448.
Bacillus amylobacter, 103.
Bacillus lepidophagus arcuatus, 294, 301.
Bacteria, 120, 289, 318, 331, 396.
   of the coal, 294.
   oldest known, 30, 42, 290, 312.
Bacterial activity, 103.
Bacteridium, 301.
Bacteriology, fossil, 289-322.
Bacterium, 30, 300.
Baltic amber, insects of, 287.
Bandelier, A. F., 490.

Barrell, Joseph, 77.
Bartels, Paul, 350.
Barycrinus hoveyi, 308.
Bassler, R. S., 46, 286.
Bathycrinus, 34.
Batujeff, N., 354.
Bavaria, 326, 340.
Becquerel rays, 78.
Bees, Leaf cutting, 107.
Bell, Sir Charles, 329.
Belly river series, 327.
Berry, Edward W., 99.
Bertrand, 103.
Bilharziosis, 397.
Bingham, Hiram, 487.
Birds, ancient, 326.
Bison, 118, 129, 156, 218, 278, 280.
Bloch, Ivan, 453.
Blood corpuscles, fossil, 165, 169, 296.
Bloodletting, 453.
Bolivia, recent trephining in, 356, 490.
Bopyridae, 288.
Bos africanus, 174.
Bothriolepis canadensis, 292, 320.
Bothrodendron, 102.
Bouchard's nodosities, 405.
Brachet, 360.
Brachiopods, 54.
Brains, 167, 180, 331.
Branchioplax washingtoniana, 288.
Breasted, J. H., 22, 380.
Broca, Paul, 350, 357.
Broili, F., 338.
Brown, Barnum, 123.
Buckland, Wm., 61.
Buffalo horn used in cupping, 454.
Buffalo skull, use of sacred, 363.
Bull, ancient, 349, 380.
Bull-frog, 119.
Bullet wound in bison, 130.
Burgessia bella, 50.
Byssacanthus, 297.

Caenomyces, 104.
Calculus, vesical in ancient Egypt, 396.
Calendar, introduction of, 22.
Callosities, 101.
Callus, 101, 115, 138.
Camarasaurus, 165.
Cambium, 101.
Cambrian crustaceans, 50.
Camels, fossil, 69, 88, 175, 236, 282, 325, 338.
Camptosaurus browni, 69, 245, 256.
Canadia setigera, 48.
Canadia spinosa, 48.
Canaliculi, 119.
Canary Islands, primitive surgery in, 360.
Carabelli, George C., 354, 493.
Carboniferous, 285, 310.
Caries, 71, 221, 225, 294, 300-303, 348, 405, 432.
  origin of, 222.
  sicca, 67.
Carnivore, Eocene, 154.
Cartilage cells, 117.
Case, E. C., 116, 129.
Cash & Hick, 105.
Castellani, Aldo, 287.
Caterpillars, 107.
Catopterus gracilis, 329.
Cautery, 357, 358, 361, 386, 502, 516.
Cave bear, 80, 254, 276, 354.
  gout, 66.
Cecidomyiids, 107.
Cetiosaurus leedsi, 154.
Chaetodon, osteoma in, 171.
Chalicotheres, 126.
Chibcha, 487.
Chihuahua, 455.
Chilly Naranjo, 360.
Chronology of Egypt, 389.
Chulpa, 358, 494.
Cicatrice, 101.
Cicatrization, 101.
Cimoliasaurus, 325.
Cladosporites, 105.
Cladosporites fasciculatus, 112.
Clams, Miocene, 58.
Clarke, John M., 21, 92, 242, 283, 286, 308.
Clidastes, 184.
Clift, William, 63.
Cliona, 287.
Coccosteus acadianus, 292, 320.
Cockerell, T. D. A., 343, 378.
Cohoes mastodon, 221, 224.
Coleoptera, 343.
Colles' fracture, 352.
Columbus, sailors of, 354.
Commensalism, 284, 310.
Compsognathus longipes, 326, 331, 340.
Conwentz, 106.
Cook, Harold, 175, 236, 258, 270, 282.
Coprolites, 295, 312.
  bacteria of, 295.
  Permian, 295, 304, 322, 336.

Copts, 166, 432.
Cordaixylon, 292.
Corset, orthopedic, 462.
Cotte, Charles, 74, 221.
Coulter, J. M., 105.
Crane, fracture in femur of, 128.
Cretaceous, 169, 212, 327.
Cribra cranii, 398.
Cribra orbitalia, 399, 420.
Crinoids, 32, 110, 283, 285, 308, 310.
Crocodile, 90, 174, 328.
Crustacea, 33, 99, 288.
Crutch, primitive, 454, 460.
Ctenodus, 297.
Cultures of bacteria fossilized, 316.
Cumberland cave, 253, 276.
Cuvier, Baron, 28, 62, 82, 326.
Cynocephalus, 410.
Cystids, 110.

Daphaenus felinus, 67, 246, 272.
Darwin, Charles, 77.
Dean, Bashford, 27, 327, 330.
Déchelette, 380.
Demon, 357.
DeMorgan, J., 388.
Dermoid cyst of the scalp, 409, 438.
Derry, D. E., 401, 409.
Devonian, 92, 291.
Diceratherium Cooki, 270.
Dictyospongidae, 286.
Dimetrodon incisivus, 116, 136.
Dinosaurus, 122, 161, 190, 192, 245, 320, 326, 341.
Dinosaurs, Three Horned, 69, 88, 124, 134, 160, 245.
Diospyros, 104, 114.
Diplococci, 292.
Diplodocus, 67, 90, 182.
Diploë, sinus in, 127.
Disease, geological evidences of, 25, 92.
 origin of, 35, 91.
 definition of, 29.
Dog, fossil, 67, 246, 272.
Dollo, L., 222.
Dolmens, 358.
Drepanodus, 225.
Drew, G. Harold, 290.
Dromocyon vorax, 125.
Dubois, E., 347.
Duckworth, W. L. H., 115.

Eaton, Geo. F., 388, 492.
Ebers' papyrus, 395.
Eccles, R. G., 288.
Ectoconus, 124.
Edaphosaurus cruciger (fracture in), 116, 132, 136, 244.
Eel worms, 107.
Egyptians, 166, 220, 387, 450.
Eldonia ludwigi, 56.
Elephant tusk, 242, 320.
Emprosthotonos, 323-327.
Engelhardt, H., 105.
Eocene leaf, 114.
Eocene mammals, spondylitis deformans in, 174.
Eosiren libyca, 70.
Eotherium aegyptiacum, 70.
Erlangen, 62, 166.
Escomel, Edmundo, 489.
Esper, E. J. C., 62.
Etheridge, Robert, 285.
Eurypterids, 342.
Excrescence, 88, 232.
Exostoses of dentine, 242.
Exostosis, 170, 243.
Extinct diseases, 26.
Extinction, 99, 341, 345.
Extinction of races, 341.

Falls, F. H., 312, 330.
Feces, fossil, 294, 314.
Felix, J., 105.
Fibers of Sharpey, 120, 173, 204.
Fish bone, bacteria in, 318.
Fishes, caries in, 222, 294.
 opisthotonos in, 328.
 pleurothotonos in, 328.
Fistulae, alveolar, 221.
Flâcherie, 35.
Fleming, George, 91.
Flint knife, use of, 364, 376, 422, 454.
Flood, 61.
Florissant shales, 329, 343, 378.
Flux, 101.
Focal infections, 222.
Foci, 395.
Foote, J. S., 119.
Fossil, 24.
Fossilization, 24, 166, 324.
Fouquet, 388.
Fraas, E., 284.

Fractures, 115, 152, 353.
among early mammals, 124.
in dinosaurs, 122.
Pleistocene, 62, 80, 126.
the oldest known, 116, 136.
Triassic, 121, 160.
Freeman, 455, 460.
Fric, A., 107.
Fungi, fossil, 103, 112, 316.
spot, 104, 114.

Gaillard, Claude, 24.
Galls, 107, 110, 114, 286, 310.
Gastropod, 110, 286.
Gaudry, Albert, 295.
Geddes, Sir Auckland, 348.
Geikie, 78.
Geinitz, 108.
Geode, a crinoid, 286, 310.
Geosaurus gracilis, 328.
Giantism, 68, 90, 251.
Giant wolf, 128, 253, 272.
Gibbon, 287.
Gilmore, Charles, 69, 116.
Glass sponges, 30.
Glossina veterna, 343, 378.
Glyptodonts, 245.
Gods of nature, influence of, 361.
Goeppert, H. R., 101.
Goldfuss, A., 62.
Gorilla, 115, 229.
Gorjanovic-Kramberger, 354.
Goundou, 488, 498.
Graefe, Albrecht von, 63.
Graff, L. von, 285, 310.
Graph, 36, 44.
Guanche skulls, 360.
Gummosis, 101.
Gundu, 488.

Haemangioma, 163-165, 182, 192-200.
Haematuria, 397.
Hall, James, 34, 224.
Hamilton shales, 286.
Hatcher, J. B., 67, 188, 272.
Haversian system, 119, 163.
Hemin reaction, 167.
Hemorrhage, stoppage of, 349, 362.
Hermit crabs, 285.
Herring, fossil, 328.
Hick, 105.
Hirsch, August, 23, 395.
Histology of mosasaur bone, 204-210.
Histology of Permian fractures, 118, 142-146.
Höhlengicht, 66, 354.
Holden, H. S., 101.
Holland, W. J., 164.
Holothurian, 56.
Holocystites, 110.
Horn core, broken 88.
Horn core, fracture in, 88, 126.
Horse, three-toed, 221, 238, 249, 282.
Howorth, H. H., 342.
Hrdlička, Aleš, 25, 350, 452.
Huacos, 489, 530-532.
Huene, F. von, 121.
Hutchinson's teeth, 354, 493.
Huxley, T. H., 77.
Hyaena, 28, 62.
Hydractinians, 285.
Hydrocephalus, 401.
Hypacrosaurus, 123.
Hyperostosis, 90, 245.
Hypertrophy, 58, 246, 353, 466.
Hysterites cordaitis, 104.

Ichthyodorulites, 294.
Iguanodon, 166.
Images, clay, representing Pott's disease, 452, 472.
Immunity
in modern invertebrates, 34.
in Paleozoic animals, 30.
Incas, 487.
Incisions of the scalp, 361.
Infantile paralysis, 408, 426.
Infections, chronic, 243.
Infrabasals of crinoid in regeneration, 34.
Insects, activities of, 106, 108, 287.
Isopod, parasitic, 288.
Instruments, primitive surgical, 520.

Java, man of, 347, 382.
Jeanselme, 354.
Jeffrey, E. C., 101.
Jigger, 490.
Jones, F. Wood, 167, 397.
Jordan, David Starr, 328.
Jurassic, 71, 326, 328, 336.

Kabyl tribes, 356, 386.
Kansas, 118, 170, 186, 293.
Keith, Arthur, 370.
Kellogg, V. L., 288.
Keloids, 364.

Kelvin, Lord, 78.
Keokuk geodes, 310.
Kerunia, 284.
Keyes, C. R., 286.
Kings of Egypt, 389.
Klebs, Arnold C., 22, 389.
Knies, J., 66.
Knowlton, F. H., 107.
Kolbe, H. J., 108.
Koelliker, A., 119, 292.
Kowalevsky, 35.
Krapina, man from, 354.
Kufstein, 68, 254.
Kusta, J., 108.
Kyphosis, 378.

Labyrinthodonts, 293, 341.
Lacunae, 119, 320.
Lamellae, 320.
Land, 105.
Langdon, 453.
Lasius, 287.
Laurinoxylon, 112.
Le Baron, Jules, 22, 347, 350.
Lehmann-Nitsche, 360.
Leidophyte, 106.
Leidy, Joseph, 28, 221, 224, 234.
Leishmania, 489.
Leishmaniosis, 489, 530.
Leontiasis, 448.
Lepidostrobus cone, 105.
Leprosy, 489.
Leptolepis sprattiformis, 328.
Leptothrix, 228.
Lesquereux, L., 112.
Létulle, 488.
Lias, 328.
Liége, 64.
Limnocyon potens, 252, 268.
Lipoids, 167.
Lordosis, 350.
Lorraine, 44.
Lortet, L. C., 24, 388, 397, 416.
Loxonema, 31.
Loxoplocus, 31.
Lucas-Championnière, 357.
Lucius lucius, 288.
Lull, R. S., 69, 341.
Luxation, congenital, 504.
Lyell, Charles, 64, 77.

Mair, W., 166.
Malaria, 397.
Malformations, 33.
Mallophaga, 288.
Mammoth tooth, 223.
Manouvrier, 347, 358.
Manatus, 228.
Mariut desert, 175.
Markham, Sir Clements, 486.
Marsh, O. C., 161, 188.
Martin, H. T., 11, 163, 171.
Mastodon americanus, 127, 158, 180, 224, 240, 344.
Mastodon floridanus, 224.
Matthew, W. D., 37, 77, 238.
Mayas of Yucatan, 23, 485.
Mayer, 62.
McCurdy, G. G., 360.
Measurements of geologic time, 78.
Medicine men, 362.
Medusa, 56.
Megalohyrax, 223.
Melancholia, cure of, 360.
Menes, 22.
Merneptah, 392.
Merriam, John C., 128.
Merychippus campestris, 221, 223, 238.
Merycochoerus rusticus, 270.
Meschinelli, A., 104.
Mesosaurus brasiliensis, 330.
Metastasis, 71.
Metchnikoff, E., 35, 91.
Metriorhynchus, 71, 90.
Micrococcus, 42, 290, 296, 298, 312.
Micrococcus devonicus, 291.
Micrococcus lepidophagus, 298-300.
Microsphaera, 35.
Minot, C. S., 36.
Miocene, 328.
Mississippian, 308, 310.
Mitchell, J. K., 408.
Moravia, 70.
Moropus, 134.
Moropus, fracture in, 126, 152.
Mosasaurs, 70, 169, 184, 202, 246, 262.
Mounds, Indian, 349, 358, 451.
Mucor, 105.
Mucor combrensis, 105.
Mummies, 167, 392, 403, 424.
Mummified animals of Egypt, 24, 388, 397, 410.
Muskox, 129, 160.
Mycelia, 106, 316.
Mycelites ossifragus, 225, 292.

Mycorhiza, 106.
Mycorhizonium, 106.
Myeloxylon, 101.
Mylodon robustus, 70, 129.
Mystriosaurus bollensis, 328.
Mystriosuchus plieningeri, 121, 160.
Myxidium lieberkühni, 288.
Myzostomids, 285, 286, 310.

Nagana, 343.
Nahua, 487.
Nature of ancient diseases, 38.
Neanderthal man, 348, 382.
Necator americanus, 287.
Necrosis, 69, 115, 245, 256, 262, 266.
Nefermaat, 403.
Neolithic man, 347.
Neolithic period, pathology during, 292, 347, 349, 356, 380.
Newton, 70.
Neuro-toxin, 323.
Nigua, 490.
Niobrara Cretaceous, 169, 186.
Nothosaurs, 90.
Nubia, 403.
Nubian deserts, 293.
Nutritional disturbance, 268.

Obolus, 54.
Odontoblast, 242.
Oil, use of boiling, 360.
Oligocene, 67, 105, 270, 287, 329, 334, 343.
Oliver, F. W., 105.
Onchus, 297.
Onychaster flexibilis, 284, 308.
Oochytrium, 105.
Oogonia, 105.
Opabinia, 105.
Opabinia regalis, 50.
Ophiacodon mirus, 136.
Opisthotonos, 323-340.
Opisthotonos in molluscs, 323.
Orang, 542.
Ordovician, 286.
Oreodonts, 260.
Osborn, H. F., 70, 289, 327, 342, 354.
Osteitis, alveolar, 221.
Osteodentine, 232.
Osteohypertrophy, 118, 140, 282.
Osteoid tissue, 118, 173, 293.
Osteoma, 170, 171, 212, 493, 504.
Osteomalacia, 252, 268, 493.
Osteomyelitis, 130, 138, 150, 218, 244, 272, 278, 303, 512.
Osteoperiostitis, in mosasaur, 172, 202.
Osteophytes, 170, 406.
Osteoporosis, 420, 436.
  in ancient Egypt, 398.
  in ancient Peru, 538.
Osteosarcoma, 62, 402, 434.
Osteosclerosis, 118, 140.
Owen, Sir Richard, 68, 129, 188.
Ox, wild, 349.

Pachyostosis, 69, 90, 251.
Paget's disease, 348, 448.
Palaeomyces, 105.
Paleobotany, 99-114.
Paleolithic man, 348, 363.
Paleolithic period, Pathology during, 348.
Paleontology, 25.
Paleopathology, definition of, 21.
  importance of, 22, 28.
  Ruffer's methods in, 393.
Paleophytopathology, 29, 99.
Paleospinax priscus, 336.
Paleozoic, 44, 99.
Palm wood, 105.
Pansinusitis, 493, 512.
Pantolambda, 174.
Parasitism, 30, 96, 101, 283, 287, 308-310.
  origin of, 283.
  geological evidences of, 96, 110.
Parker, Charles, 161.
Pathology, Mesozoic, 247, 262.
  Paleozoic, 110.
Pébrine, 35.
Pellets, 101.
Pelycopods, 287.
Pelycosauria, 325.
Perenosporites antiquarius, 104.
Periderm, 102.
Periodontitis, 352, 405.
Permian, 116, 136, 146, 244, 303, 330.
Peronosporoides palmi, 105.
Peru, ancient disease of, 357.
Pestalozzites sabalana, 104.
Pezophaps solitaria, 70.
Peytonia nathorsti, 56.
Phagocytosis, 35, 387.
Pharaoh of Exodus, 392.
Pharmical knowledge of North American Indians, 455.
Phenacodus, 125, 223.

Phycomycetes, 104.
Physeter macrocephalus, 228.
Phytopathology, 99.
Phytosauria, 121.
Pigs, Oligocene, 126.
Piltdown skull, 348.
Pithecanthropus erectus, 287, 347, 382.
Pizarro, 486.
Plants, fossil, 99.
Platecarpus coryphaeus, 169, 171, 216, 262.
Platyceras, 110, 283, 310.
Platycnenia, 493.
Platygonus, 253, 276.
Platystrophia, 31.
Pleistocene, duration of, 78.
  pathology of, 66, 176, 274, 288, 344.
Plesiosaurs, 325, 330.
Plesiosaurus macrocephalus, 328, 336.
Pleurocanthus, 297.
Pleurodictyum problematicum, 310.
Pleurothotonos, 323, 327.
Pliocene camel, spondylitis deformans in, 175.
Plioplatecarpus marshi, 70.
Poisons, cerebro-spinal, 323.
Poliomyelitis, stela showing, 408, 426.
Poncet, 397, 410.
Ponderosa, 31.
Ponzi, G., 108.
Potonie, H., 105.
Pott's disease, 402, 422, 452.
Pott's disease, during Neolithic, 350, 378.
Pre-Columbian diseases, 23, 452.
Prehistoric, definition of, 22, 350.
Pressure atrophy, 409, 438.
Primates, fossil, 354.
Pristiophorus suevicus, 225.
Prolapsus of viscera, 400, 432.
Proliopithecus, 287.
Proneusticosaurus, 69, 252.
Pseudarthrosis, 125, 126, 148, 156.
Pseudo-parasitism, 286.
Psoas abscess, 402, 424.
Pterodactyls, 184, 325.
Pterodactylus longirostris, 326.
Pterodactylus micronyx, 338.
Ptycholepis marshi, 329.
Puberty, 397.
Puccineae, 105.
Pulp stones, 236.
Pycnodonts, 225.
Pyorrhea, 221, 238, 432.
Pythium, 35.

Quenstedt, F. A., 108.
Quichua, 486.

Radioactive substances, 78.
Rafinesquina alternata, 44.
Ramses II, 392.
Rancho la Brea, 128, 260, 272.
Rathbun, Mary J., 33, 288.
Raymond, Paul, 347, 353.
Recuperation, 33.
Red hand, 363.
Regeneration, 32.
Relation of early races of man, 370.
Renault, B., 30, 97, 105, 222, 244, 291, 294.
Renier, A., 102.
Resins, 101.
Rhachitis, 70, 397, 410, 450.
Rhinoceros, 223, 243, 250, 258, 270.
Rickets, 70, 397, 410, 450.
Riggs, E. S., 68, 123, 176, 247, 258.
Rinderpest, 343.
Rondelle, 358, 384.
Rosellinites, 105.
Roux, Canals of, 292.
Ruffer, Sir Marc Armand, 21, 92, 174, 347, 387, 388, 414.

Saber tooth cat, 128, 176, 218, 258.
Saccardo, 104.
Sand flea, 490.
Sandwith, F. M., 389.
Scalp incisions, 358, 372.
Scapula, aberrant foramen in, 192.
Scarification, 362, 376.
Schaafhausen, 348.
Schenk, 112.
Schistosomiasis, 396.
Schistosoma haematobia, 397.
Schlosser, Max, 68, 254, 450.
Schmerling, P. C., 64, 91, 398.
Schuchert, Charles, 32.
Schwalbe, Gustav, 348.
Sclerosis, 458.
Sclerotites brandonianus, 105.
Scoliosis, 352.
Scott, W. B., 128.
Seitz, A. L. L., 119, 166, 293.
Senescence, 36, 44.
Senility, 36.
Sequestrae, 80, 350.

Seward, A. V., 101.
Shamanism, 357, 361, 490.
Shark, fossil, 336.
Shattock, 392.
Shurafa, 409, 438.
Sigillaria, 108.
Silhouettes of hands, 363, 374.
Silicification, 294.
Sincipital T., 358, 502.
Sinus, necrotic, 138, 158, 246.
Sinuses, 243.
Skull fracture, 344.
Sloth, giant, 70, 128.
Sloth, Pleistocene, fracture in, 70.
Sloup, 65.
Small-pox, earliest evidence of, 395, 430.
Smilodon, 176, 218, 253, 258.
Smith, G. Elliot, 167, 392, 396, 440.
Smith, Worthington, 105.
Snail shells, 110, 283.
Snake creek beds, 175, 282.
Soemmering, Samuel Thomas von, 62, 326.
Solenhofen slates, 324.
Sollas, W. J., 374.
Sonders, 292.
Sosuska, 70.
Spear point injury, 474.
Sphaerospermum, 105.
Spine, Permian, 116, 244.
Spines, significance of, 26.
  fracture in, 116.
Splints of bark, 440, 454, 460.
Spondylitis deforman, 90, 128, 164, 173, 182, 218, 220, 353, 403, 484.
Sponges, 30, 110, 287.
Springer, Frank, 33, 44.
Staasfeld, 291.
Starfish, 284.
Stegosaurus, 246.
Stems, parasitized crinoid, 310.
Stenomylus, 325, 334, 338.
Stone Age, injuries during the, 349, 374, 380.
Stopes, M. C., 101.
Strabops, 342.
Stramonium, 455.
Stromer von Reichenbach, E., 223.
Strotocrinus regalis, 310.
Struthiominus altus, 327, 331, 338.
Strychnine, 323.
Sudhoff, Karl, 24, 360.
Surgery, beginnings of, 352, 426, 440.
  during Neolithic, 352, 358.
  North-American Indians, 453.
  Peruvian, 359, 494.
  primitive, 360, 386.
Sutton, J. Bland, 171.
Swabia, 326.
Symbiosis, 283, 284, 286.
Symbos cavifrons, 129, 160.
Syphilis, 352, 355, 388, 411, 448.
Syphilis, congenital, 354.

Tait, 78.
Talipes equinus, 408.
Tamayo, M. O., 489.
Tarahumare Indians, 455.
Tattooing, 364.
Taxocrinus colletti, 33.
Taxodium, 102, 107.
Teeth, pathology of, 444, 446, 492.
Tegmen of crinoid, 310.
Telentospora milloti, 105.
Teleosaur, 328.
Terataspis, 44.
Teratology, 107.
Tertiary, 106, 343.
Thaumatosaurus victor, 331.
Theoretical aspects of Paleopathology, 287.
Thoma, 406.
Thread-mould, 225, 291, 293.
Tibia, 380, 466.
Tiger, saber-tooth, 128, 173, 176, 218, 258.
Titanotherium robustum, 70, 125, 148.
Todeskampf, 330.
Tomistoma dowsoni, 174.
Trabeculae, 117.
Trachodon annectans, 192, 254.
Traumatisms 32, 88, 154, 253.
Trephining, 347, 368, 455.
Trephining, prehistoric, 352, 356, 358, 368, 384.
  Incan, 490, 524, 528.
  Egyptian, 409.
Triassic, 324, 329, 341.
Triepel, 292.
Trilobites, 36, 52, 99, 343.
Triceratops, 69, 88, 134, 245.
Triceratops serratus, 69, 124, 160.
Trinil, 347.
Troxell, E. L., 69.
Trypanosoma brucei, 343.
Trypanosomiasis, 343, 366.
Tsetse flies, 343, 378.
Tubercle of Carabelli, 354, 493.

Tuberculosis, 350, 353, 402.
Tuberculum anomalus, 354.
Tumor, 402, 434, 453.
Tusk elephant, odontoma in, 242.
Twenhofel, W. H., 44.
Tyrannosaurus, 165.

Ulna of Neanderthal man, 348, 382.
Ulodendron, 102, 112.
Urinary schistosomiasis, 397.
Ursus spelaeus, 62, 80, 86.
Uta, 489, 512, 530.

Van Tieghem, P., 30, 103, 291.
Variant of Sincipital T., 359, 502.
Variola, 395.
Vendrest, Neolithic burials at, 358.
Venus rileyi, 31, 58, 60.
Venus tridacnoides, 31, 58, 60.
Verneau, R., 360.
Verruga Peruviana, 488.
Vertebral tuberculosis, 350, 378, 402, 422, 472.
Vesical calculus, 396.
Vioa, 287.
Virchow, Rudolf, 65, 66, 84, 225, 353, 374, 382.
Volz, W., 68.

Wagner, 326.
Walcott, C. D., 11, 42, 103, 290, 312.
Walther, Ph. von, 63, 84, 91.
Waptia fieldensis, 50.
Watson, D. M. S., 102.
Wedl, canals of, 225, 292.
Weiss, F. E., 106.
Whale, cachelot, 236, 242.
Wheeler, W. M., 287.
White, D., 104.
Whitford, A. C., 105.
Whitney, W. F., 452.
Wieland, G. R., 69, 88.
Williamson, W. C., 105, 107.
Williston, S. W., 116, 136, 169, 184, 188, 325.
Wilson, Thomas, 349.
Wiman, C., 329.

Xylophagus arthropod, 107.
Xyne grex, 328.

Yale University, 11, 125, 127, 162, 493.

Zittel, Carl Alfred von, 84.
Zygosporites, 105.